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Experiences of Advanced Driver Assistance Systems amongst Older Drivers

An evidence review for the Department for Transport

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Date: 6 February 2020

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This project was carried out in compliance with ISO20252

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Based on the CRediT taxonomy.¹

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Acknowledgements: The authors would like to thank Catherine Davie, Claudia Senese, and Helena Titheridge, members of the Department for Transport advisory group for providing guidance on the requirements and scope of this project.

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¹ CRediT is a taxonomy, developed by Casrai (Consortia Advancing Standards in Research Administration Information), that includes 14 roles used to present the contributors to scholarly output. It aims to more accurately represent the range of contributions researchers make to a report. <https://casrai.org/credit/>

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Glossary

Advanced Driver Assistance Systems (ADAS) can be classified as automatic systems, warning systems, information systems, and hands-free devices. The following glossary provides a list and definition of all ADAS covered in this review, grouped by type of system.

Automatic systems		
Technologies that automatically respond to driving conditions with little or no input required from the driver.		
Technology	Definition	Alternative name
Adaptive headlights	Automatically change the direction of the light beam when steering left or right on curved roads.	<i>Adaptive light control</i>
Adaptive Cruise Control (ACC)	Automatically adjusts the vehicle speed to maintain a constant gap between the vehicle and the vehicle ahead.	<i>Intelligent speed adaption systems; automatic cruise control</i>
Automatic parking	Automatically manoeuvres vehicle into a parking space to perform parallel, perpendicular, or angle parking. Typically requires some driver input.	<i>Parking assist; self-parking system; semi-automated parking assist</i>
Automatic windscreen wipers	Automatically activates when rain is detected.	
Autonomous Emergency braking system	Monitors traffic conditions in the vehicle's path and provides a visual or auditory warning. Automatically brakes if no action is taken by the driver.	<i>Automatic braking; automatic emergency braking; emergency braking</i>
ECall	Dials emergency services (either 999 or 112) after a collision or accident	<i>Automotive emergency response system; Emergency response system</i>
Lane Keep Assist	Detects when the vehicle is moving out of a lane and provides a visual, auditory or vibration warnings. If no action is taken by the driver, steps are automatically taken to ensure the vehicle stays in its lane.	<i>Automatic lane maintain; lane assist; LKA</i>
Intersection crossing assist	Monitors oncoming traffic at a road junction or across the opposite driving lane. If the gap is too small to permit a turn, activates a visual or auditory warning and prevents the vehicle from moving.	<i>Intersection navigation; right turn assist</i>
Traffic jam assist	A form of ACC that estimates the distance of the vehicle from other vehicles and maintains distance by accelerating or	<i>Traffic jam assistant</i>

	decelerating whilst the vehicle is in a traffic jam.	
Warning systems		
Technologies that provide warnings to drivers about driving conditions in the form of visual or auditory signals or vibrations.		
Technology	Definition	Alternative name
Blind spot detection	Detects vehicles in the driver's blind spot and provides a visual, auditory or vibration warning.	<i>Blind spot monitor; blind spot warning; side view assist lane change assist</i>
Cross Traffic Detection System	Detects traffic behind the vehicle and provides a visual or auditory warning.	
Fatigue alerts	Detects driver drowsiness and fatigue and provides a visual or auditory warning.	
Forward collision warning	Detects slower moving or stationary objects in the path of the vehicle and provides auditory warnings to prevent or reduce the severity of collision.	<i>Collision avoidance systems</i>
Lane Departure Warning (LDW)	Detects when the vehicle is moving out of a lane and provides a visual, auditory or haptic warning.	
Parking sensor	Detects and alerts drivers when there is a danger of collision with a pedestrian, animal or other object when the vehicle is reversing.	<i>Backing aids; reverse assist</i>
Pedestrian detection sensors	Detects and alerts drivers when there is a danger of collision with a pedestrian, animal or other object whilst moving forward.	
Information systems		
Technologies that provide information to drivers regarding the vehicle and driving conditions.		
Technology	Definition	Alternative name
In-vehicle concierge systems	Connects driver with a person who can answer questions and provide information and other services (e.g. it can tell you where the nearest petrol station is).	
Navigation system	Displays a map on a screen and/or provides auditory instructions to help the driver navigate to their destination.	<i>Navigation assistance; Sat Nav</i>
Night vision enhancement	Uses infrared sensors to detect people, animals and objects at night. The information is displayed on a video screen in the vehicle.	
Rear-view cameras	Video cameras located at the rear of the vehicle. Images are shown on a video screen in the vehicle to assist with parking and reversing.	<i>Rear view parking displays</i>

Speed limit informer	Continuously informs the driver of the speed limit for the road they are driving on.	<i>Intelligent speed assist</i>
Hands-free devices		
<i>Technologies that allow drivers to communicate through their voice.</i>		
Technology	Definition	Alternative name
Active Voice control	Allows the driver to control vehicle features using voice commands.	
Integrated Bluetooth mobile phones	Connects the vehicle with a mobile phone to allow the driver to make and receive phone calls using the vehicle's speakers and dashboard interface.	<i>Integrated Bluetooth</i>

Executive summary

This study provided a synthesis of 23 studies looking at older people²'s experiences of and attitudes towards ADAS. Half of the studies reviewed came from North America, the others largely from the UK and Europe.

Awareness of ADAS

- Between half and three-quarters (53-77 percent) of older people in England were aware of at least one type of automatic ADAS³, after being prompted with a list of these technologies.
- **Awareness of automatic ADAS decreased with age amongst older people:** In England, those aged 75 and older had the lowest rate of awareness and those aged 55 to 64 had the highest rate of awareness (53 percent vs 77 percent).
- **Awareness of automatic ADAS also varied according to the type of technology.** For example, 40-68 percent of older people in England were aware of automated parking systems whereas only 13-30 percent were aware of traffic jam assists.

Ownership of ADAS

- **Information and warning systems were the most commonly owned** forms of ADAS amongst older drivers; in an American study 28 to 47 percent of older drivers owned information or warning systems and 1 percent owned automatic systems. This may not be a consequence of a conscious choice, but a reflection of what technologies were available in the vehicles older drivers bought.
- **Male drivers with a higher income and education** level owned a significantly higher number of ADAS.

Experience with ADAS

- Less than half (45 percent) of older drivers in England had experienced automatic ADAS. Experience with automatic ADAS was highest amongst drivers aged 55 to 64 (36 percent) and lowest amongst drivers aged 75 and over (28 percent).

Learning to use ADAS

- The most common method for learning how to use ADAS amongst older drivers was through **on-road experience**; between 40-50 percent of older drivers in the United States learnt to use ADAS in this manner.
- More older females never learnt to use the ADAS equipped in their vehicle compared to older males; in an American survey for example, only 65 percent of older females with adaptive cruise control in their vehicles had ever learned to use the system compared to 94 percent of men.

² The age that constitutes whether a driver is considered “younger” or “older” differed amongst the studies included in the review. The youngest age at which a driver was considered “older” was 55 years and the oldest was 70 years.

³ Automatic ADAS are a type of ADAS that automatically respond to driving conditions with little or no input required from the driver. Examples are: traffic jam assist, lane keep assist, adaptive cruise control. This review also looked at warning systems (such as blind spot detection and fatigue alerts) and information systems (such as Sat Nav or night vision enhancement), which still require driver's input.

Frequency of use of ADAS and changes in driving behaviours

- **Warning systems** were the **most frequently** used type of ADAS amongst older drivers; those with the systems reported using fatigue alerts and blind spot detection 92 percent of the time but automatic parking systems only 6 percent of the time.
- ADAS designed to assist drivers with **both short and long journeys** (e.g. blind spot detection) were used relatively frequently, whereas systems designed to assist drivers primarily with long journeys (e.g. fatigue alert) were used less frequently.
- Older drivers, particularly women, reported that adaptive headlights and navigation systems allowed them to drive more frequently at night and on unfamiliar roads.

Perceptions and opinions of ADAS

Some studies investigated the perceptions of ADAS amongst older drivers with no experience of using ADAS (see '*Before using ADAS*' below) and other studies investigated the perceptions of ADAS amongst older drivers with experience of using ADAS (see '*After using ADAS*').

Before using ADAS

- Older adults were **interested in using ADAS**; in one American study, 80 percent of older drivers reported that they were willing to use ADAS.
- Older drivers reported being interested in using ADAS because they believed that ADAS could make routine driving activities **easier**. They believed ADAS might be particularly helpful for those with age-related impairments or themselves, should they develop age-related impairments, such as vision impairment and mild memory loss. For example, warning systems could act as an “extra set of eyes”.
- However, older drivers were concerned that the **technology** might be **confusing** because of the complexity of the systems.
- **Warning and information systems** were **more desirable** to older drivers than automatic systems because: (1) older drivers did not want to give up control over their vehicles and (2) these systems were perceived as more useful, as they solved common driving problems, such as limited blind spot visibility.
- **Willingness to use ADAS was linked to perceptions of utility**; older drivers reported being more willing to use systems that they perceived to be more useful (for example, older drivers reported being more likely to use blind spot detections than automatic windshield wipers as the former were perceived as more useful).

After using ADAS

- The perceptions and opinions older drivers had of ADAS before and after using them did not differ greatly, except for some evidence suggesting that older drivers may become less concerned about the negative effects of ADAS as they learnt to use them and experienced how they could increase safety.
- The level of **acceptability** of ADAS amongst older drivers was generally high compared to younger drivers; in one American study 68 percent of older drivers liked or very much liked ADAS, versus 42 percent of younger drivers.
- **Warning and information systems** were the **most acceptable** form of ADAS amongst older drivers.
- Opinions on the **utility** of different ADAS types varied by whether the system solved a widely acknowledged problem and how effectively it solved that problem. For example, older drivers believed that systems that aided their ability to see at night or monitor their blind spot were more useful than systems that aided their

ability to navigate intersections because they found the former tasks more difficult than the latter.

- Opinions about the **usefulness** of ADAS also appeared to be **moderated by age-related impairments** of older drivers but **not by age itself**.
 - Amongst older drivers, those with age-related impairments believed that navigation and automatic systems were more useful than those without impairments.
- In general, older drivers **felt safer** in vehicles equipped with ADAS compared to vehicles without. ADAS technologies that provide information and warnings and sense dangers were perceived as increasing safety the most.
- ADAS could create **new problems and concerns** for older drivers:
 - **False alarms** created concern and were perceived as annoying. Information and warning systems were reported to give false alarms up to 30 percent of the time. However, compared to younger drivers, older drivers were more forgiving of false alarms.
 - **Distraction** caused by ADAS created concern amongst older drivers. Around one in 10 older drivers were concerned that ADAS would cause distraction while driving. Compared to younger drivers, more older drivers reported being distracted by navigation systems and active voice control.
 - Older drivers were concerned about becoming **over-reliant** on ADAS but there was no evidence this happened. Over-reliance could lead to drivers failing to react or take control when necessary.

1 Introduction

1.1 Background

In response to the Ageing Society and Future of Mobility Grand Challenges set out in the Industrial Strategy White Paper (HM Government, 2017), the Department for Transport are interested to know the implications of an ageing population for transport. A key question is how demand for transport will change as the population ages, how transport services will need to change to meet this demand, and how older adults will receive these changes.

Advanced Driver Assistance Systems (ADAS) have been developing rapidly over the past decade. ADAS are a collection of technologies that assist with driving tasks such as braking, monitoring, steering and parking and include devices such as adaptive cruise control (ACC), emergency braking, automatic parking, and lane departure warning (LDW) systems. ADAS can be retrofitted to the vehicle, installing a navigation system for example, but are most often already installed in the vehicle at the time of purchase.

ADAS have the potential to augment or compensate for loss of functioning associated with older age (Rhiu et al., 2015). The potential benefits of ADAS to older drivers (and others) include:

- Driving safely for longer (Young and Bunce, 2011);
- Knowing when to stop driving (Musselwhite, 2010);
- Increased mobility (Duncan et al., 2015; Shergold, Lyons and Hubers (2015);
- Reduced depression, loneliness and isolation (Emmerson et al., 2013).

However, there are also a number of possible reasons why ADAS may not be used by older people:

- Low perceived usability and acceptability of ADAS (Eby and Molnar, 2012);
- Unaffordability and unavailability of ADAS (Guo, Harvey and Edwards, 2017).

1.2 Why this evidence review is needed

Primary studies and literature reviews of ADAS suggest that ADAS hold possibilities for increasing the mobility and better meeting the transport needs of older people. However, there are mixed findings and some literature suggests that because of the unique limitations and needs of older adults, ADAS may not offer the same possibilities to older adults as they do to the general population or may need to be adjusted to fit the abilities of older adults. In order for the Department of Transport to better understand whether and how ADAS can meet the needs of older people over the next five to ten years, the information and findings from individual studies on ADAS need to be synthesised and processed in a systematic way. The evidence on older adults' views and experiences with ADAS is diverse and comes from studies of varying degrees of quality. This evidence review is needed to critically appraise the body of evidence and bring together different studies to draw conclusions that can effectively inform Department for Transport policies.

1.3 Research questions

Based on the Department for Transport's interest in the implications of an ageing population for transport, this evidence review addressed the following research questions:

1. What is the awareness, availability, affordability and acceptability of ADAS amongst older people?
2. What evidence is there on the impact of ADAS on the mobility and mode choices of older people?

Addressing the questions outlined above is intended to help the Department for Transport understand the implications of ADAS for delivering transport services that meet the needs of older people over the next five to ten years.

1.4 Study objectives and potential implications

This evidence review aims to:

1. Determine the availability, affordability, awareness and acceptability of key ADAS to older people;
2. Assess the potential impact of ADAS on the mobility and mode choices of older people over the next five to ten years;

Filling these gaps is expected to help inform policy in the following areas:

1. Potential of ADAS to increase mobility and vehicle use;
2. Raising awareness of the benefits of ADAS to older people;
3. Managing transition to stopping driving effectively;
4. Changes to regulations/legislation to enable effective use, prevent unsafe use, and produce design guidelines;
5. Changes to driving licence issuing for older drivers. For example, licensing regulations may no longer need to be age dependent but dependent on the presence of ADAS in vehicles.

2 Methodology

2.1 Overview

This section outlines the process of selecting and synthesising the 23 studies included in this report. See Chapter One of the Technical Report for a detailed methodology.

From the beginning, it was decided that around 20 studies would be synthesised and included in the review. Therefore, the goal of the searching, appraisal, and screening stages were to identify the most relevant and highest quality studies. Three principles were followed to ensure that the studies included in the final review were relevant and high quality:

1. Cover as many outcomes as possible whilst ensuring that the evidence base for each outcome covered was deep enough in order to make meaningful comparisons and conclusions. Outcomes covered three categories: (1) attitudes and perceptions towards ADAS, (2) the effect of ADAS on driving behaviour; and (3) the effect of ADAS on long-term health and social outcomes. See Table 1:1 in the technical report for a detailed list and description of the outcomes.
2. Include studies that are high quality. A large evidence base for a particular outcome does not ensure that the conclusions drawn will be reliable; if the studies are of low quality, the validity of the results will be low.
3. Include studies to best answer the research questions. In light of the above principles, decisions had to be made about which outcomes were the most relevant to the implications of ADAS for the mobility of older people in the UK.

To compile the final list of studies, five steps were taken. At each step, an additional level of screening was conducted to narrow the number of studies and ensure that the most relevant and highest quality studies were included in the review.

2.2 The methodological process

2.2.1 Literature Search

The following four sources of information were used to identify relevant studies:

1. Google scholar;
2. Specialised transport websites;
3. The Web of Science;
4. Transport experts.

In addition, backward and forward citation analysis was carried out for sources identified through Google Scholar and the transport experts.

Each result obtained through the four sources was screened at the title and abstract level by three researchers. Studies that met the following inclusion criteria were retained and appraised in step two:

1. Cover at least one type of ADAS.
2. Cover at least one of three relevant outcomes (attitudes and perceptions, driving behaviour, or long-term health and social outcomes).

-
3. Offer original findings. Studies either had to be empirical or, if a literature review, offer original conclusions rather than summarise findings.

2.2.2 Relevance appraisal

In total, 131 of the studies identified through the search process met the inclusion criteria. At this stage, the goal was to identify the 50 most relevant studies. To do so, the abstracts of the studies were scored for relevance. Studies were scored on five different areas of relevance and scored out of a possible five points:

1. Number of ADAS covered (*more than one type of ADAS=1 point*)
2. Older adults (*older adults deliberately sampled or data on older adults analysed separately= 1 point*)
3. Date of publication (*published during or after 2013=1 point*)
4. Number of outcomes (*more than one outcome =1 point*)
5. Study setting (*set in the UK=1 point*)

Twenty-seven studies scored four or above, 40 studies scored three, 36 studies scored two and 27 studies scored one or lower.

2.2.3 Initial screening

It was decided that studies with a score of four or five would automatically be moved on to the next round of screening, as these were the most relevant studies. However, because only 27 studies scored four or higher, studies with a lower relevance score were also selected to be included in the list of 50. Following the principles outlined above, as well as the goal to include as many studies that sampled drivers in the UK, priority was given to studies that covered outcomes not covered within the 27 studies already identified. Studies with a relevance score of three were prioritised, but if there was no study with a score of three covering a relevant outcome, studies with a lower score were included.

2.2.4 Detailed screening

After narrowing the number of studies to 51 and being confident that these studies were relevant to the review's research questions, 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.

Quality appraisal was done following the Weight of Evidence (WoE) framework that assesses study quality 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 were developed and studies were assessed out of possible score of 24. For each study, a quality appraisal and key finding form was completed.

Once all studies were appraised and summarised, they were prioritised based on their WoE score and the outcomes they covered. Amongst the 51 studies, attitudinal outcomes were covered the most often, followed by driving behaviour outcomes. It was decided that the attitudinal outcomes, along with two driving behaviour outcomes 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 validity; if each outcome was only covered by one study, it would be difficult, and unreliable, to draw substantial conclusions.

The average WoE score for all 51 studies was 15. There were 19 studies that covered the desired outcomes and had 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 were high quality reviews but scored low because the scoring system was developed for empirical studies) but were in fact high quality reviews. Therefore, 23 studies were included in the final review.

2.2.5 Data extraction and synthesis

The two final steps in the review were to: (1) extract all relevant results and (2) synthesise and compare each result to draw conclusions about older adults' experience with ADAS. Two coders used a data extraction tool. 169 separate results were extracted from the 23 studies.

To synthesise and develop the findings outlined below, the results were sorted into 11 general topics. Within each topic, the results were then analysed and compared for similarities and differences. 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 in general 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) was taken into consideration.

3 Results

3.1 Overview of the included studies

3.1.1 Summary of the number of articles included and excluded

The literature search returned over 300 results. Through abstract and title screening, 131 studies were retained for further relevance screening. After scoring each study for relevance, 81 studies were excluded due to low relevance. The 51 studies that remained were screened at the full text level for quality and relevance. Through this process, 23 studies were retained and included in the review. See figure 1 in the Technical Report for a detailed description of the number of studies included and excluded at each step (BurrIDGE, Mayer, Vaganay, 2019).

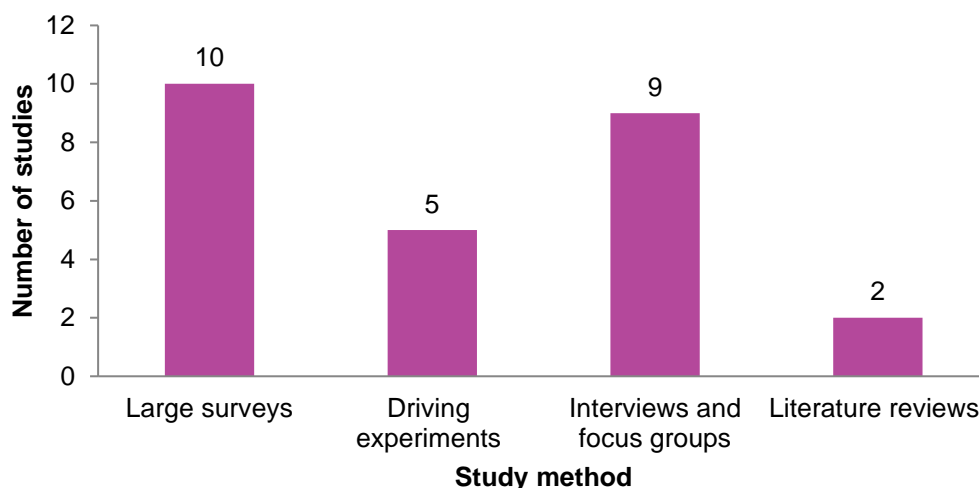
3.1.2 The methodology used in included studies

Quantitative (e.g. large surveys) and qualitative (e.g. semi-structured interviews with a small number of participants) studies were included in the review, along with literature reviews that made substantive conclusions. There were four types of methodologies used in the studies:

1. Large surveys: sampled respondents (between 90 and 5000) and used a survey to elicit responses on use of, and attitudes towards, ADAS.
2. Driving experiments: participants used a driving simulator with ADAS or actual vehicles and reported their experiences.
3. Interviews and focus groups: sampled a small number of respondents (between 20 and 35) and carried out semi-structured individual or group interviews.
4. Literature reviews: reviewed the existing literature on ADAS and older drivers and produced new, synthesised findings.

Figure 3:1 presents the study methods of the studies included in the review (note: the total number sums to 26 rather than 23 because three studies used multiple methods).

Figure 3:1 Study methods of included studies



3.1.3 The type of ADAS covered in the included studies

Across the included studies, 23 different types of ADAS are covered. The ADAS that are covered can be grouped into four different categories:

1. Hands-free devices: technologies that allow drivers to communicate with the vehicle or others through their voice (e.g. active voice control).
2. Information systems: technologies that provide information to drivers regarding the vehicle and driving conditions (e.g. navigation systems).
3. Warning systems: technologies that provide warnings to drivers about driving conditions in the form of visual or auditory signals or vibrations (e.g. blind spot detection).
4. Automatic systems: Technologies that automatically respond to driving conditions with little or no input required from the driver (automatic parking).

Information, warning, and automatic systems can be imagined as existing along a continuum from manual to fully-automated, with some systems capable of performing two or all three functions. For example, emergency braking systems will first provide a visual and auditory warning if a danger is sensed. If no action is taken by the driver, the system will then automatically brake. See the glossary at the beginning of the review for a full list and definition of each type of ADAS.

3.1.4 The age range covered in the included studies

The age that constitutes whether a driver is considered “younger” or “older” differs amongst the studies included in the review. The youngest age at which a driver is considered “older” is 55 years and the oldest is 70 years. Most studies set the minimum age at 55 or 65 years.

Table 3:1 shows the distribution of definitions across the included studies (note: the total number does not sum to 23 because the literature reviews did not set a minimum age). For consistency, “older drivers” is defined here as aged 55 or older and “younger drivers” is defined at aged 54 or younger (many studies included in the review compared older drivers as a group to younger drivers as a group). This is an arbitrary definition, following the definitions chosen by the authors of the studies reviewed; it is possible that some drivers may benefit from ADAS before aged 55 and some may benefit well afterwards. Age 55 is used here as a guide and is not meant to be an exact cut-off.

Table 3:1 Age threshold and country used in each study

Study reference	Age threshold	Country
Bellet et al. (2018)	70	France
Crump et al. (2016)	55	USA, Canada, China
Department for Transport (2018)	None (all age groups included)	UK
Dukic Willstrand et al. (2015)	70	France, Sweden
Duncan et al. (2015)	65	USA
Eby et al. (2018)	65	USA
Eby et al. (2016)	65	USA
Gish et al. (2017a)	60	Canada
Gish et al. (2017b)	60	Canada
Guo et al. (2010)	None (review)	Several (review)
Jenness et al. (2008)	65	USA

Kang et al. (2016)	55	South Korea
Lee et al. (2014)	None (age recorded as continuous variable)	USA
Marshall et al. (2014)	55 (Group 1) and 65 (Group 2)	USA
Motamedi et al. (2017)	60	USA
Musselwhite et al. (2007)	68	UK
Payyanadan et al. (2017)	65	USA
Payyanadan et al. (2018)	65	USA
RICA (2014)	55	UK
Son et al. (2012)	55	South Korea
Souders et al. (2016)	65	USA
Souders et al. (2017)	65	USA
Trübswetter et al. (2013)	60	Germany

3.1.5 The countries represented in the included studies

Studies set in the UK were prioritised in the searching and screening process. However, compared to the number of studies set in the US and other countries, there have only been a small number of studies set in the UK. In total, over half of the included studies sampled respondents in North America and only three studies sampled respondents in the UK (See Table 3:1).

4 Findings

The findings are presented thematically. The first four sections report findings about the awareness and ownership rates of ADAS and the context of how and when ADAS is used. The fifth section, perceptions and opinions about ADAS, reports findings about the perceptions and opinions around the acceptability and utility of ADAS amongst older drivers who have never used ADAS and amongst drivers with experience of ADAS.

4.1 Awareness of ADAS

Awareness of automatic ADAS in England amongst older drivers is between 50 to 75 percent. Older drivers with no awareness of ADAS are unlikely to use the systems even if they are fitted in their vehicle. Therefore, it is important to know the level of awareness of ADAS amongst older drivers in order to inform policies that are meant to encourage take-up of ADAS. Five studies reported on the awareness of ADAS amongst older drivers. Most recently, a representative survey of 3,500 respondents conducted in England on public attitudes towards transport and technology asked respondents whether they had heard of six different types of automatic ADAS:

1. Automated parking
2. Adaptive cruise control
3. Automatic emergency braking
4. Lane assist
5. Remote-control drive or remote-control parking
6. Traffic jam assist

Results were broken down by age groups (with three groups of older drivers: aged 55-64, 65-74, and 75+). Table 4:1 shows the awareness levels of each age group for each type of automatic ADAS and awareness of automatic ADAS overall. Amongst older people, between 53 to 77 percent were aware of any of the automatic ADAS presented, with awareness declining as respondents aged. Respondents between the age of 55-74 were significantly more aware of any type of automatic ADAS than respondents over the age of 75 (in this age group 45 percent were *not* aware of any type of automatic ADAS, significantly more than any other age group). Older respondents were the most aware of automated parking systems: between 40 to 68 percent of older respondents reported having heard of the system. Awareness among older respondents was lowest for traffic jam assistants, with only between 13 to 30 percent of older respondents aware of the system. Again, respondents aged 55-74 were significantly more likely to have heard of both systems, as well as the five other systems (Department for Transport, 2018).

Levels of awareness differ by sample drawn on and the questions asked.

Awareness was found to be relatively lower in studies investigating *spontaneous awareness* (i.e. when examples of ADAS were not given) and relatively higher in studies investigating *prompted awareness* (i.e. when examples of ADAS were given). For example, a UK study asking older drivers if they could think of a technology that could keep them on the road longer found that 41 percent of respondents could do so. (RICA, 2014). In contrast, in another UK study, respondents were given a list of different automatic ADAS and asked only to indicate if they had heard of the systems. Results were much higher (55 percent to 73 percent depending on the technology). Likewise, a German study investigated awareness of ADAS among owners of a mid- to top-range vehicle who knew at least one ADAS (Trübswetter and Bengler, 2013). Unsurprisingly, among 32 adults, 27 knew the term “Driver Assistance System”

(Trübswetter and Bengler, 2013). Amongst those that knew about ADAS, drivers learned about the systems most often through friends (31 percent) and the press (23 percent) and least often through the television or car dealers (11 percent each; Trübswetter and Bengler, 2013). Interestingly, when asked the intended purpose of ADAS, drivers without experience of ADAS echoed the purpose set out by manufacturers, that the systems were intended to support the driver.

Table 4:1 Awareness of automatic ADAS by age in England

Type of ADAS	Age of respondents						
	16-24	25-34	35-44	45-54	55-64	65-74	75+
Unweighted base	412	533	472	486	496	584	555
Automated parking (%)	60	61	64	68	68	58	40
Adaptive cruise control (%)	39	45	49	55	52	50	30
Automatic emergency braking (%)	40	46	49	56	50	48	32
Lane assist (%)	30	41	46	48	41	36	23
Remote-control drive or remote-control parking (%)	25	31	36	35	32	29	15
Traffic jam assistant (%)	21	26	30	31	30	26	13
Aware of any (%)	73	74	77	78	77	72	53
Aware of none (%)	21	23	19	19	21	27	45

Source: Department for Transport, 2018.

Awareness of automatic ADAS differs little between younger and older adults up to age 74 but drops significantly at the age of 75 in England. As table 4:1 shows, awareness of automatic ADAS appears to increase as the age of cohort increases, up to the third oldest age group (age 54 to age 64), at which awareness of automatic ADAS begins to decline (the decline is slight amongst the 54 to 64 and then begins to decline more rapidly amongst older age groups). This trend is apparent for awareness of any type of ADAS and the six specific types of automatic ADAS. The 55 to 64 age group has very similar levels of awareness compared to the younger age groups and in fact, have higher levels of awareness compared to the youngest age group (16-24) and similar levels of awareness compared to the 35 to 44 age group. The 65 to 74 age group have lower levels of awareness compared to middle aged drivers (age 35 to 54) but similar awareness levels as young drivers (aged 16-34). Finally, those aged 75+ have significantly lower levels of awareness than all other age groups, when looking at awareness of at least one automatic ADAS type or of individual automatic ADAS. Among all other age groups, awareness of any automatic ADAS ranges from 72 to 78 percent (it is highest amongst the 45 to 54 age group) and then drops down significantly to 53 percent among 75+. Interestingly, two studies (Sounders and Charness 2016; and Crump et al., 2016) drawing on a sample of American and Chinese, Canadian, and American respondents, respectively, did not find a difference in the familiarity with ADAS amongst older and younger drivers. However, both studies grouped respondents 55 and older together and compared this group to all younger respondents, meaning differences within the older age group may be hidden and offset by higher levels of awareness amongst respondents aged 55 to 74 within the older age group.

4.2 Ownership of ADAS

The most prevalent types of ADAS owned by older drivers are warning and information systems with lower levels of automation. Amongst the 15 different technologies assessed in a questionnaire study in the United States, the most prevalently owned systems were integrated Bluetooth mobile phones (47 percent), parking sensors (40 percent) and navigation systems (28 percent). The least common were automatic parking (1 percent), fatigue alerts (1 percent), and night vision enhancement (0.1 percent; Eby et al., 2018).

In support of these results, focus groups held with older drivers in France found that 14 out of 30 participants owned a speed limit informer, a warning system, and/or a basic cruise control system. However, no participants owned an ACC system (Bellet et al., 2018; Dukic Willstrand et al., 2015). This is reflected in work using semi-structured interviews with older drivers in Germany. While basic cruise control (a non-ADAS feature that allows drivers to set a preferred speed to maintain) was owned by 75 percent of participants, ACC was owned by only three percent of participants (Trübswetter and Bengler, 2013). Similarly, parking sensors were owned by 75 percent of drivers interviewed while automatic parking systems were owned by only nine percent. This suggests that less automatic forms of ADAS are more commonly owned by older drivers compared to automatic systems. However, it is important to note that this may not be a consequence of a conscious choice, but a reflection of what technologies are available and common in the type of vehicles older drivers buy; it is not clear how many older drivers buy a vehicle with ADAS solely because it has ADAS.

Male drivers with a higher income and education level own a significantly higher number of ADAS (Eby et al., 2018). Two studies considered demographic differences in relation to ownership. Ownership rates across ACC and navigation systems for focus group participants in France were shown to be higher for older male drivers compared to older female drivers (Bellet et al., 2018). Similarly, longitudinal survey data from the United States found that the number of men who own at least ten out of the 15 in-vehicle technologies tested was significantly higher than the number of women (Eby et al., 2018). It is possible that these findings are due to differences in the types of vehicles men buy compared to women (i.e. men may be more likely to buy the type of new vehicles that are fitted with ADAS compared to women). Prevalence was further shown to significantly differ by income and education level, with highest levels of ownership amongst participants earning over \$100,000 (USD) or among participants with university degrees (Eby et al., 2018). Again, this may be because those with higher incomes are likely to spend more on their vehicles compared to those with lower incomes, and hence are more likely to buy vehicles where ADAS comes fitted as standard.

4.3 Experience with ADAS

At least 55 percent of older drivers in England do not have experience with ADAS. Five studies investigated usage rates of different ADAS amongst older drivers (Bellet et al., 2018; Dukic Willstrand et al., 2015; Eby et al., 2018; Department for Transport, 2018; Trübswetter. and Bengler, 2013). In the transport and technology survey conducted by Department for Transport (2018) in England, among those that had heard of automatic ADAS and had a valid UK driving licence, only 28 to 36 percent of older drivers reported having used at least one type of automatic ADAS. As table 4:2 shows, use was highest amongst respondents aged 55 to 64 and lowest amongst drivers aged 75 and older, but the difference in rates is not significant⁴. These percentages are much lower than those reported in the United States. A longitudinal questionnaire completed in the United States found that 57 percent surveyed have at

⁴ Not significant at the 5% level.

least one ADAS in their primary vehicle (Eby et al., 2018). It is possible that ADAS are more prevalent, desirable, and/or attainable in the United States compared to England. Amongst those aged 65-74 and 75+, the system the highest percentage of respondents had used was ACC: 19 percent of respondents aged 65 to 74 had used the system and 12 percent of respondents aged 75 and older has used the system (the difference between the two groups is significant). The least used system, across all age group, was remote-control drive or remote-control parking: 3 percent of respondents aged 55 to 64 had used the system and 2 percent of the respondents aged 65 and over has used the system.

Table 4:2 Use of automatic ADAS by age in England*

Type of ADAS	Age of respondents						
	16-24	25-34	35-44	45-54	55-64	65-74	75+
Unweighted base	193	310	306	330	304	355	231
Adaptive cruise control (%)	8	18	24	24	20	19	12
Lane assist (%)	7	16	20	16	15	8	6
Automatic emergency braking (%)	7	12	18	18	11	11	5
Automated parking (%)	7	14	17	15	13	6	8
Traffic jam assistant (%)	1	6	8	7	6	5	4
Remote-control drive or remote-control parking (%)	1	4	6	4	3	2	2
Used any (%)	19	33	41	40	36	30	28
Used none (%)	65	58	52	52	55	63	68

Source: Department for Transport, 2018.

(*) Among those who have heard of ADAS and hold a valid UK driving license.

Older drivers over the age of 65 have very limited experience with automatic ADAS compared to older drivers aged 55 to 64 and younger drivers. Similar to rates of awareness, experience with automatic ADAS in England appears to increase with age up to the age of 54, after which it declines slightly between the age of 55 to 64, and drastically after the age of 65. Except for drivers aged 16 to 24, drivers aged 65 and over report the lowest rates of having used automatic ADAS. The younger age cohort of older respondents (aged 55 to 64) report similar levels of use as respondents aged 25 to 44 (Department for Transport, 2018).

4.4 Learning to use ADAS

4.4.1 Methods and sources of learning

Amongst older drivers the most common method of learning how to use ADAS is on-road experience. Two studies investigated methods of learning to use ADAS. A longitudinal survey of 2,990 older drivers in the United States found that for 12 out of 15 technologies assessed, older drivers most commonly learned by figuring the system out for themselves (49 percent), from the dealer (20 percent) or via the owner's manual (12 percent). The least common methods were the internet (0.1 percent) and family or friends (four percent). Findings show that parking sensors and blind spot detection were most likely to be self-taught (Eby et al., 2018). The frequency of self-teaching is supported by a large survey of 5,137 drivers aged over 65 in the United States, which found that 43 percent of respondents learned to use their Navigation systems, parking

sensors and rear-view cameras via on-road experience (Jenness et al., 2008). However, a significantly higher percentage of younger respondents (61 percent) learned through on-road experience (Jenness et al., 2008). No studies investigated why drivers choose to learn through on-road experience the most often compared to other methods of learning. However, it may be because, as explained below in section 4.3.2, older drivers find that overall ADAS are relatively easy to use and therefore, they do not require any additional methods of learning.

Older male and female drivers differ in their methods for learning how to use ADAS and a higher number of older female drivers do not learn how to use the ADAS in their vehicles. Despite the preference for self-learning amongst older drivers in general, a greater number of older male drivers compared with female drivers learned about ACC (80 vs. 52 percent) and rear-view cameras (53 percent vs. 28 percent) by using the owner's manual. In addition, more older male than older female drivers used on-road experience to learn about parking sensors (52 percent vs. 41 percent) and ACC (45 percent vs. 26 percent). Thirty-five percent of women with ACC had not yet learned to use the system, compared to only six percent of men (Jenness et al., 2008). This is supported by results from the US longitudinal survey discussed above, which found that women were less likely to use an owner's manual or teach themselves about ADAS and were more likely never to have learned to use them or to have learned from a dealer compared to men (Eby et al., 2018).

4.4.2 Ease of learning to use ADAS

Overall, ADAS are relatively easy to learn for older drivers. Two large survey studies based in America investigated how easy it is for older drivers to learn to use specific ADAS (Eby et al., 2018; Jenness et al., 2008). According to a longitudinal survey of nearly 3,000 older drivers in the United States, 70 percent of respondents found it 'very easy' to learn how to use parking sensor systems. The cross-traffic detection system was also found to be 'very easy' to learn how to use by the majority of respondents (80 percent) and none felt it was 'very difficult' to do so. The difference between female and male respondents was not significant for either forms of ADAS system (Eby et al., 2018).

In comparison to younger drivers, it is harder for older drivers to learn how to use ADAS. A longitudinal survey of over 5,100 older drivers in the United States found that although levels of overall difficulty remain low, a significantly higher percentage of older respondents found it harder to learn about navigation systems (32 percent of older drivers vs. 22 percent of younger drivers) and rear-view cameras (15 percent of older drivers vs. eight percent of younger drivers) than younger respondents. There was no difference in age for ease of learning regarding parking sensors and ACC (Jenness et al., 2008). However, it is important to note that no direct results of the significance testing are reported in this study and therefore it is unknown if the differences found (or not found) are meaningful.

4.5 Frequency of use of ADAS and changes in driving behaviour

4.5.1 Frequency of use

Warning systems are used the most frequently amongst older drivers. In vehicles equipped with fatigue alerts, blind spot detection, forward collision warnings, cross-traffic warnings, rear-view cameras, and LDW, drivers report they most frequently

turned these systems on (Eby et al., 2016). Drivers with fatigue alerts and blind spot detection reported using warnings used these technologies 92 percent of the time. In comparison, automatic parking and in-vehicle concierge systems were used only six percent and three percent of the time, respectively (Eby et al., 2018). It should be noted that only a small number of respondents in this study owned fatigue alerts and automatic parking.

Frequency of use appears to be somewhat moderated by the purpose of each system, with systems that are useful on all road types used the most frequently.

Navigation systems are used around 30-40 percent of the time and are used most frequently on unfamiliar routes (however, some drivers reported they use navigation systems even when they knew where they are going for increased confidence), (Bellet et al., 2018; Jenness et al., 2008; Payyanadan et al., 2017). ACC is used most often on motorways (Eby et al., 2016). Warning systems such as forward collision warning systems or blind spot detection systems, however, can be of use on all roads; therefore, it is unsurprising that these systems are turned on more frequently. However, for certain systems, such as automatic parking that could be used daily, desires to remain in control of the vehicle, as will be outlined below, may play a role in the infrequent use. As shown below, the frequency of use of the different systems relates to the acceptability, and perceived utility, safety, and trustworthiness of these systems.

The effect of age on the frequency of use of ADAS is unclear. A literature review of 271 studies concluded that older drivers use ACC more frequently than younger drivers but surprisingly use night vision enhancements less often, despite being more likely to benefit from the system, but this may be because older drivers are less likely to travel at night (Eby et al., 2016). In a survey of over 5,000 drivers in California, older drivers used navigation systems less frequently than younger drivers (Son and Park, 2012). However, in a large cross-national American survey comparing 13 different ADAS, that included night vision enhancement, navigation systems, and ACC, there was no significant difference in the frequency of use of each technology amongst older and younger respondents, except for integrated Bluetooth mobile phones, which younger drivers used more often (Eby et al., 2018).

4.5.2 Change in driving hours and road types due to ADAS

Navigation systems and adaptive headlights give older drivers greater confidence to drive at night and on unfamiliar routes. Two studies investigated how the use of ADAS affected when and where older adults drove (Eby et al., 2016; Jenness et al., 2008). Adaptive headlights encouraged older drivers to drive at night (Eby et al., 2016). One study asked drivers if they would change their driving behaviour if the adaptive headlights they currently use were replaced with conventional headlights; compared to seven percent of younger drivers, 13 percent of older drivers said they would limit their driving at night. Further, amongst older drivers, 20 percent of female drivers would avoid going to unfamiliar places and would avoid dark roads compared to nine percent of males (Jenness et al., 2008). Navigation systems influence drivers in similar ways with a literature review concluding that navigation systems lead to older drivers travelling more frequently during times and on roadways they would normally avoid (Eby et al., 2016).

4.6 Perceptions and opinions of ADAS

Drivers with and without experience of ADAS both have perceptions and opinions about the acceptability, utility, trustworthiness, safety, ease of use, and value of ADAS. Understanding the perceptions and opinions of older drivers towards ADAS is useful to designers of ADAS who can use the information to adapt the systems in response. As

well, this information is useful for campaigns to encourage the take-up of ADAS, as the positive features of ADAS can be emphasised and effort can be made to dispel concerns about ADAS. Six studies included in the review investigated the perceptions of ADAS amongst older drivers with no experience of using ADAS and 21 studies investigated the perceptions of ADAS amongst older drivers with experience of using ADAS (some studies included both types of drivers). Even though no study includes data on the change in perception before and after experience with ADAS amongst the same respondents, these two sets of findings can act as a proxy for this data to investigate whether drivers without ADAS experience have the same opinions as drivers with ADAS experience. This section begins by presenting the opinions about ADAS amongst older drivers without ADAS experience and then presents the opinions and beliefs about ADAS amongst drivers with ADAS experience.

4.6.1 Before-use perceptions of ADAS

The six studies that investigate before-use attitudes of ADAS uncover perceptions of ADAS through surveys, interviews, and focus groups after demonstrations of different types of ADAS.

Acceptability before-use

The majority of older adults are interested in using ADAS. Six studies investigated older drivers' desire to use ADAS and their opinions about ADAS before using a system (Bellet et al., 2018; Dukic Willstrand et al., 2015; Marshall, Chrysler and Smith, 2014; Motamedi and Wang, 2017; Souders and Charness 2016). The studies found that there is a high level of interest amongst older adults about ADAS. For example, in one study, a large majority (82 percent) of older adults believed that people their age would want ADAS in their vehicles; there was no variation in opinion of ADAS by age, gender, and income (Souders and Charness 2016).

Older drivers believe in the potential for ADAS to assist with driving but have concerns. There is a general positive attitude towards using ADAS among drivers without experience of ADAS but there is some hesitation due to concerns over complexity and automation. The desire to use ADAS comes from the belief that the systems could aid older drivers in routine driving activities. For example, older adults thought that ADAS can operate as an "extra set of eyes" which would mean drivers would not have to turn their head as much and it would be of assistance to drivers with poor vision. However, drivers expressed some hesitation; there was concern that having multiple systems in the car may be too confusing and drivers did not want to give up control over their vehicle (Marshall, Chrysler and Smith, 2014).

Older drivers are most interested in information and warning systems. Compared to automatic systems, such as automatic parking or ACC, older drivers expressed a greater interest in using information and warning systems, such as blind spot detection or forward collision warnings. Understanding which systems and features are of most interest to older drivers is useful to know so that ADAS can be designed to meet the interests and desires of older drivers. When asked what systems they would find the most useful, older adults in two studies chose blind spot detection systems (Marshall, Chrysler and Smith, 2014; Motamedi and Wang, 2017). In one study, the system was given a score of 4.25 out of five for its potential (Motamedi and Wang, 2017). Other information and warning systems are also perceived as potentially useful and desirable. In particular, systems that provide information on the current speed limit or provide a warning when the speed limit has been exceeded were seen as useful, compared to systems that automatically reduce driving speed (Bellet et al., 2018; Dukic Willstrand et al., 2015). In addition, drivers expressed an interest in intersection

crossing assist and navigation systems (Bellet et al., 2018). Interest in navigation systems came from hearing other users talk about the benefits of the systems and the belief that the device would be useful for the future, particularly with route planning, travel time, and refuelling information. Navigation systems displayed through heads-up displays or augmented reality technologies were perceived as being particularly useful as they are considered to better support the needs of older drivers compared to the display screens currently used (Dukic Willstrand et al., 2015).

Willingness to use

There is a general enthusiasm amongst older drivers to use ADAS. Four studies investigated older drivers' willingness to use ADAS amongst drivers in the general population without experience of ADAS (Duncan et al., 2015; Motamedi and Wang, 2017; Souders et al., 2017; Souders and Charness 2016). Given the general positive attitude of older drivers towards ADAS before-use, it is unsurprising that the majority of older drivers would like to use ADAS. Compared to 56 percent of older drivers who were willing to use automatic vehicles, 80 percent were willing to use ADAS (Duncan et al., 2015). Drivers with higher incomes and higher technological efficacy were found to be more willing to use ADAS, compared to those with lower incomes and low technological efficacy and there was no difference by age or gender (Souders and Charness 2016). These findings suggest that the perceived benefits of ADAS in relation to the costs and affordability of them is higher for those who have higher incomes and have higher technological efficacy compared to those on low incomes and those with lower levels of technological efficacy.

Willingness to use ADAS appears to be linked to perceptions of utility and the health of older adults (Duncan et al., 2015; Motamedi and Wang, 2017; Souders et al., 2017; Souders and Charness 2016). Just as acceptability varies depending on the type of ADAS considered, so does the willingness to use ADAS. An American study asked respondents to identify the likelihood they would use different ADAS (Motamedi and Wang, 2017). Blind spot detection was given the highest rating (4.04 out of 5, with 5 being extremely likely) and automatic windshield wipers were given the lowest (2.93 out of 5). This is unsurprising given that when asked to rate how helpful each technology would be, blind spot detection was rated the highest whereas automatic windscreen wipers were rated the lowest. The authors found that likelihood of use differed by health of respondents. Respondents with multiple health conditions, such as vision impairment and muscle weakness, indicated the highest likelihood of using ADAS whereas respondents with no concerns indicated the lowest likelihood.

The effect of age on the willingness to use ADAS is unclear. Two studies investigated the relationship between age and willingness to use different types of ADAS among drivers who have not used ADAS. Within and across the two studies, there was no pattern between age and willingness to use ADAS. In a small American study, controlling for demographic variables, technological efficacy, familiarity with ADAS and self-reported vision, older people were found to be more willing to use ACC and LDWs compared to younger people but there was not a significance difference found between the two groups in terms of willingness to use lane keep assist, emergency braking systems, and automatic parking (Souders et al., 2017). In a larger American study that controlled for similar factors (technological efficacy, income, and gender) there was no difference in the willingness to use ADAS amongst older and younger drivers (Souders and Charness 2016).

4.6.2 After-use opinions

The 21 studies that investigate after-use attitudes of ADAS do so through two methods: either through surveys, interviews, and focus groups of older drivers who own vehicles with ADAS (15 studies) or through experiments that involve participants driving a vehicle equipped with ADAS at least once (six studies). There are no differences between these two types of studies; opinions about ADAS appear to be similar amongst older drivers who have tested the systems once and drivers who own vehicles with ADAS.

Acceptability of ADAS and reflections on future purchases

Amongst older drivers, there is a generally high level of acceptance of ADAS and older drivers prefer and accept ADAS more than younger drivers. Seven studies investigated opinions about ADAS after-use (Crump et al., 2016; Eby et al., 2016; Gish et al., 2017a; Jenness et al., 2008; Kang, Wang and Kim, 2016; Musselwhite and Haddad, 2007; Son and Park, 2012). Acceptability is measured in different ways across studies: most quantitative studies used Likert scales with questions about respondents' opinions of a system and qualitative studies asked drivers to explain what they like and do not like about the systems. Amongst drivers who had experience with ADAS, older drivers rated it more positively than younger drivers; 68 percent of older drivers liked or very much liked ADAS whereas 42 percent of younger drivers liked or very much liked ADAS (Crump et al., 2016). Even though different types of ADAS have different levels of acceptability, across types there is a higher level of preference and acceptability amongst older drivers compared to younger drivers (Crump et al., 2016; Eby et al., 2016; Gish et al., 2017a; Son and Park, 2012) – possibly because older drivers find them more useful. For example, two studies found that older drivers rated LDWs more favourably than younger drivers; in one study older drivers gave the system a mean rating of 5.6 out of seven, compared to younger drivers who gave the system a mean rating of 4.6 (with older males preferring the system slightly more than older females; (Crump et al., 2016; Son and Park, 2012). Positive opinions amongst older drivers are shaped by the view that ADAS are systems a convenience that make drivers feel more comfortable behind the wheel (Gish et al., 2017a).

Older drivers appear to want to own ADAS again. Because ADAS are often not retrofitted but come included in new vehicles, drivers may not have originally chosen to have ADAS, but rather, found themselves with it after purchasing a new vehicle. Therefore, one measure of the acceptability of ADAS is drivers' desire to own ADAS again as it reflects drivers' approval of the systems and a desire to continue to use the systems that they may not have originally chosen to own. A survey of drivers in the United States, Canada, and China asked respondents with experience of ADAS whether they would purchase a vehicle with similar technologies again and found a greater percentage of older adults would: 36 percent of older adults responded they would definitely purchase similar technologies compared to 20 percent of younger drivers (Crump et al., 2016). However, 36 percent is relatively low, and is lower than the percentages reported in other studies that report on specific technologies; for example, amongst respondents in California, 97 percent of the 667 older drivers with parking sensors would like the system again (Jenness et al., 2008). This difference may be the result of the way the questions were asked. In the former study respondents were asked to rate how likely they were to purchase similar technologies again on a scale from one to seven whereas in the latter study, respondents were asked if they would purchase the system again, with a yes or no option. It also may be the result of asking a more abstract question about all types of ADAS compared to a more concrete question about a specific type of ADAS. In terms of specific systems, a literature review of 271 studies found that rear-view cameras were the most popular,

with 95 percent of drivers wanting the system in their next vehicle and LDWs are the least, with 71-83 percent wanted the system again (Eby et al., 2016).

ADAS that perform warning or information functions are more acceptable to older drivers compared to automatic functions. Studies on the before-use preferences of older drivers found that older drivers would prefer ADAS that performed warning or informative functions, rather than automatic functions and this is echoed amongst older drivers with experience using ADAS. Drivers believed that warning functions and information functions are more important compared to assistive and fully automatic functions (Musselwhite and Haddad, 2007; Kang, Wang and Kim, 2016). For example, ACC systems that actively control speed received low support from drivers, whereas systems that provide feedback only received higher support (with drivers who frequently violate the speed limit less favourable of the systems; Eby et al., 2016). Specifically, warnings about the external environment were found to be significantly more valued compared to warnings about the driving condition or vehicle status (Kang, Wang and Kim, 2016). Older and younger drivers both preferred to have navigation information communicated both audibly and visually (63 percent and 56 percent, respectively), but more older drivers preferred audible communication only (37 percent compared to 22 percent of younger drivers; Jenness et al., 2008).

Trust in ADAS and opinions on the reliability of ADAS

Older drivers have more trust in ADAS with lower levels of automation. Six studies investigated drivers' trust in, and opinions of the reliability of, ADAS after using them. The majority of drivers did not view a lack of trust in ADAS as a barrier to using it (Trübswetter and Bengler, 2013) but drivers did not trust ADAS to make the correct choice in *all* driving situations and would like to retain the ability to override the system and prefer to be in control of the vehicle (RICA, 2014). This finding helps to explain why drivers generally prefer warning and information systems compared to automatic systems (Gish et al., 2017b; Marshall, Chrysler and Smith, 2014). In fact, one study finds that respondents rated blind spot detection (a warning/information system) most trustworthy (with a mean rating of 2.98 on a scale from zero to four) and intersection crossing assist (an automatic system) least trustworthy (with a mean rating of 1.67). This was further supported in a qualitative study in which a respondent stated "*I am in favour of any warning systems but prefer to be in control of the vehicle*" (RICA, 2014, p. 6).

Drivers have greater confidence in the reliability of their own abilities compared to the reliability of ADAS, except for drivers with age-related impairments who appear to trust the reliability of their own abilities and ADAS equally. With age, drivers can experience declines in physical mobility, eyesight, hearing, and cognition. Drivers reporting not experiencing these age-related impairments appear to be more confident in their driving abilities compared to drivers reporting experiencing these impairments (RICA, 2014, p. 6). Greater self-confidence appears to also relate to navigation systems. Opinions on the reliability of navigation systems were low and older drivers were slightly more confident in their ability to navigate while driving compared to their confidence in navigation systems (Bellet et al., 2018). Indeed, navigation systems were considered to be unreliable because they are not properly updated or did not deliver correct information about rural roads (Payyanadan et al., 2017). One study reported contrary findings: qualitative interviews with a small number of older drivers in Canada found that participants believe that ADAS enhance driver safety because the technologies are able to perform driving tasks more reliably than humans. This study focused on drivers' experiences of ADAS in relation to perception of their ageing bodies. It is possible that within this context of bodies facing physical and mental limitations, ADAS are seen as more reliable.

Opinions of the utility of ADAS

Opinions on the utility of different ADAS types vary by whether the system solves a widely acknowledged problem and how effectively it solves that problem. Seven studies investigated opinions on the utility of ADAS amongst drivers with experience of ADAS (Bellet et al., 2018; Crump et al., 2016; Dukic Willstrand et al., 2015; Eby et al., 2018; Eby et al., 2016; Guo et al., 2010; Payyanadan et al., 2017). A summary of opinions about utility can be found in table 4:3. The utility of ADAS is investigated through asking participants about how useful they believe systems to be, most often in relation to how a particular system solved a particular driving problem (for example, whether navigation systems actually aid drivers in navigating unfamiliar routes; Guo et al., 2010). The perceived utility of a system depended on the type of driving problem it solved, how efficiently it solved a problem (i.e. it does not create new problems for drivers), and whether there is a problem to solve in the first place. Therefore, it is unsurprising that when drivers did not perceive a personal benefit from using the system (because they felt they already have driving skills), the lack of perceived usefulness is considered a barrier to the use of ADAS (Trübswetter and Bengler, 2013). Attitudes about the perceived usefulness of systems are further explained by a study that found that respondents believed systems that helped to compensate for driving tasks that they found difficult more useful than systems that compensated for tasks that they did not find difficult. For example, night vision systems were found more useful than collision avoidance systems because drivers more concerned about their ability to see in the dark than to avoid other cars, objects or people (Marshall, Chrysler and Smith, 2014).

Driving systems that are highly technologically advanced but do not make the act of driving simpler are not perceived as useful as systems that make driving easier or solve a common driving problem. For example, the perceived benefit of in-vehicle concierge systems that inform drivers where the nearest petrol station is or recommends restaurants is low; 40 percent said the system improved their driving experience (Eby et al., 2018). Whereas parking sensors, blind-spot detectors, and lane-change assist systems were perceived as useful because they provide a greater sense of control to drivers by alerting them to potential risks while driving (Payyanadan et al., 2017). Table 4:1 outlines the problems that eight ADAS solve and why the systems are considered useful.

ADAS systems that reduce stress while driving are rated positively and considered as useful. According to the literature, ADAS can reduce stress levels whilst driving for older people. A literature review of older drivers' use of ADAS around the world found that four systems have been found to reduce the self-reported stress levels of drivers and are therefore considered as useful. Cross traffic detection systems, ACC, rear-view cameras, and automatic parking were all viewed as useful because the assistance they provide to drivers reduces the self-reported stress they feel while driving and parking (Eby et al., 2016).

Warning and information systems are perceived as the most useful types of ADAS. Consistent with the findings above in sections 4.5.1 to 4.5.4 that drivers prefer warning and information systems to automatic systems, ADAS that provide drivers with information about their driving environment (such as the speed limit) or alert drivers to potential dangers are perceived as the most useful types of ADAS (Bellet et al., 2018; Dukic Willstrand et al., 2015; Eby et al., 2018; Guo et al., 2010). For example, ACC systems that provided information and warnings about the speed limit were perceived as the most useful compared to systems that automatically decelerate. In particular, drivers find systems that provide information about the speed limit of the road they are currently driving on useful (Bellet et al., 2018; Dukic Willstrand et al., 2015) as it reduces the reliance on road signs.

Opinions about the usefulness of ADAS appear to be moderated by age-related impairments of older drivers but not by age itself. There are mixed findings whether opinions about the utility of ADAS differ by age amongst the general population, but amongst older drivers, there is a difference in opinions between drivers with and without age-related impairments. A large American survey found no difference in the perceived utility of in-vehicle concierge systems, emergency response systems, cross traffic detection systems, and parking sensors by age of drivers (Eby et al., 2018). The same study found no difference by age in terms of perceived usefulness of night vision systems but a literature review of 271 studies concluded that the systems provide greater benefits for younger drivers (Eby et al., 2016). A very small (20 drivers) American study found that more younger drivers than older drivers reported that LDW systems and ACC are not helpful (Crump et al., 2016). Investigating how opinions about the utility of ADAS differ amongst older drivers with different levels of health, may help to explain these findings; older drivers without age-related impairments believed information and warning systems are the most useful, whereas older drivers with age-related impairments considered navigation and automatic systems to be just as, or more, useful. Qualitative interviews with older drivers in Canada that focused on the relationship between the ageing body and ADAS, found that participants believed that ADAS are useful for counteracting age-related declines in driving performance; blind spot detection help to counteract vision loss; navigation systems assist with short-term memory loss; and warning systems assist with limited mobility (Gish et al., 2017a). In addition, a literature review found that navigation systems are particularly useful to older drivers with dementia for guidance when they are lost (Guo et al., 2010). Unlike older drivers generally, drivers with age-related impairments expressed a greater willingness to “relinquish” control over driving to ADAS; they still expressed some concern with giving full control to technology but accepted sharing responsibility for driving between themselves and the technologies (Gish et al., 2017b, p. 243). In comparison, a survey in the UK asked older drivers which technologies they believed would help to extend their driving age and found forward collision warning systems, blind-spot detection, and night-vision systems were the most popular technologies. The authors conclude that all three systems have a significant information system component and argue this shows a preference for systems that keep the locus of control with the driver (RICA, 2014). These conflicting findings suggest that amongst older drivers with age-related impairments, ADAS that assumes partial or full control are perceived as being useful as the systems can counteract these limitations. However, amongst older drivers without such limitations, opinions the utility of such systems is low.

Table 4:3 Perceived utility of different types of ADAS

Type of ADAS	Problem(s) it solves according to older drivers	Why it is considered useful by older drivers
Adaptive cruise control	Driver fatigue Maintaining the speed limit Excessive fuel usage	Helps to reduce driver fatigue, maintain the speed limit and improve fuel economy (Payyanadan et al., 2017).
Adaptive headlights	Poor visibility at night	Helps drivers to see better at night and causes less eye strain but it not considered by drivers to result in crash reductions (Eby et al., 2018; Eby et al., 2016; Guo et al., 2010).

Backing-up/parking assist	Backing-up Parking	Helps drivers avoid objects and other vehicles behind their vehicle and helps with parking, particularly fitting into tight parking spaces and parallel parking (Eby et al., 2018; Eby et al., 2016).
Emergency response system	Dialling emergency services after a collision or accident	Believed that the system could help save drivers' lives in a crash (Eby et al., 2018).
Lane change assistance and blind spot detection	Poor blind spot visibility	Can lead to increased situational awareness and reduce the amount drivers have to turn their heads (Eby et al., 2016).
Lane departure warning	Remaining with the lane	Helps drivers keep to their lane when distracted and help to reduce lane excursions, leading to a reduction in driver stress (Eby et al., 2016). Particularly helpful for long trips.
Navigation Systems	Navigating unfamiliar routes	Increases confidence of older drivers in unfamiliar areas, allows older drivers in the early stages of dementia to locate themselves and navigate back home (Guo et al., 2010). Particularly useful if it provides instructions based on landmarks and voice-guided navigation because it reduces the time drivers spend glancing at the visual display.

Opinions of how ADAS affects safety

Having a vehicle with ADAS leads to increased feeling of safety, compared to having a vehicle without ADAS. Seven studies investigated whether having ADAS equipped vehicles makes older drivers feel safer. One study found that 70 percent of respondents who had ADAS in their vehicles reported that it made them feel safer (Eby et al., 2018). This is because driving is considered a risky activity, particularly by older drivers, and ADAS are viewed as enhancing safe driving by directing drivers to perform proper and safe driving practices, such as maintaining their lane. This increase in the perception of safety makes drivers feel more comfortable (Gish et al., 2017a).

ADAS technologies that provide information and warnings, sense dangers, and allow drivers to see better or spot normally hidden dangers are perceived as increasing safety the most. Forward collision warnings, blind spot detection, cross traffic detection, LDWs, parking sensors are perceived most highly in terms of increasing safety whereas automatic parking, active voice control and ACC are perceived least highly (Crump et al., 2016; Eby et al., 2018; Jenness et al., 2008; Marshall, Chrysler and Smith, 2014; Son and Park, 2012). Again, adding to the understanding why information and warning systems are preferred over automatic systems, information and warning systems are considered to increase safety more than automatic systems. Warning and information systems help drivers to carry out driving tasks with greater certainty and confidence, while maintaining control of the vehicle. These results are found in three studies that compare the perceived safety of different ADAS. In the first, blind spot detection and cross traffic detection systems made 95

percent of respondents feel like a safer driver, while automatic parking systems only made 50 percent of respondents feel like safer drivers (Eby et al., 2018). Similarly, in the second, blind spot detection, LDWs, and pedestrian detection sensors were all given higher safety ratings by respondents than automatic windscreen wipers, ACC, and night vision cameras (Motamedi and Wang, 2017). Finally, in the third study the highest number of car owners indicated parking sensors made them safer drivers and the lowest number of car owners indicated ACC made them safer drivers (Jenness et al., 2008).

There are inconclusive findings regarding differences in the perceived safety of ADAS by age and gender. One study in the United States found that older drivers more strongly agreed than young drivers that forward collision warning made them feel safer (Crump et al., 2016). In a study set in South Korea, older drivers (males and females) reported (i) higher levels of perceived safety compared to younger females but (ii) lower levels of perceived safety compared to younger males (Son and Park, 2012). Both studies contain a very small number of participants (11 and 26, respectively) and both studies involved drivers using the system in an experimental condition once. A study in the United States found few differences or correlations in the perceived safety of different types of ADAS by age, gender, or income (Eby et al., 2018).

Opinions on the value for money of ADAS

Cost is a small barrier to the use of ADAS and perceived value of ADAS does not vary by age. Two small-sample studies investigated how older drivers perceive (i) the affordability ADAS; and (ii) their value for money. The first study focused on costs and found that the cost of ADAS was a barrier for nine percent of respondents; however, this study consisted of only 32 older adults in Germany (Souders et al., 2017). The second study focused on value for money and found no significant difference in the value given to the system by older and younger drivers, after controlling for key variables (Trübswetter and Bengler, 2013). An important caveat of the data is that because vehicles with ADAS technologies are more expensive than cars without, most studies include respondents with middle to upper incomes and few lower income respondents.

Ease and difficulty of use

Older drivers can find some ADAS are more difficult to hear, read or use than younger drivers. Six studies investigated the ease and difficulty of using ADAS amongst older drivers with experience of ADAS. Findings from earlier sections indicate that older drivers are willing to use ADAS and believe that ADAS can make driving easier and solve particular driving problems. As well, it cannot be assumed that older drivers always find ADAS more difficult to use; there was no difference found between older and younger drivers' difficulty in using ACC, and LDWs were considered less inconvenient by older drivers (Jenness et al., 2008; Son and Park, 2012). However, ADAS systems, particularly those with advanced technological interfaces, can be difficult for older drivers to use, highlighting the importance of taking older drivers' needs into account when designing ADAS (Eby et al., 2016; Guo et al., 2010). Compared to younger drivers, a greater number of older drivers found active voice controls more difficult to use, parking sensors more difficult to hear, display screens more difficult to read, and navigation systems more difficult and too complex to use.

Some authors recommend the specific needs of older drivers should be better reflected when developing new ADAS. Older drivers assess their skills and abilities for using and learning new technologies lower compared to younger drivers. According to Gish et al., their use of new technology more often depends on the availability of

training and the perceived trade-off between the utility of a system and the difficulty learning how to use it (Gish et al., 2017b). Driving with ADAS technologies requires older drivers to learn new habits and train their bodies in new driving routines; for example, no longer looking over their shoulder but interpreting visual, auditory, and spatial feedback (Gish et al., 2017b). Drawing on qualitative data collected through interviews and focus groups, some authors have concluded that ADAS systems should not increase workload or the amount of information that needs to be processed (Gish et al., 2017b; Payyanadan et al., 2018).

Concerns with ADAS and problems created by ADAS

ADAS can create new problems and concerns for older drivers. The above sections have highlighted how ADAS can increase driver confidence, make driving easier for older drivers, and increase perceptions of safety. However, eight studies reported that ADAS can create new problems and raise new concerns for older drivers. These concerns include ADAS cluttering the dashboard, increasing driving workload leading to overload, a loss of control, and alerts occurring too late for the driver to react or not occurring at all (Eby et al., 2016; Musselwhite and Haddad, 2007). Unsurprisingly, given earlier results regarding drivers' preferences for and opinions of automatic versus warning and information systems, drivers reported that ACC creates the most problems and concern, whereas rear-view cameras create the least (Jenness et al., 2008). There are three areas that create concern amongst drivers: false alarms and annoyance with the systems, distraction caused by the systems, and over-reliance on the systems.

False alarms create concern and are perceived as annoying. Despite being the most popular type of ADAS, warning and information systems can give false alarms to drivers. Forward collision warnings, LDWs, blind spot detection, cross-traffic warnings and rear-view parking assist systems were all reported to give false alarms up to 30 percent of the time and drivers found this annoying (Eby et al., 2016; Trübswetter and Bengler, 2013). False alarms occurred most often in bad weather and in response to stationary objects. Compared to younger drivers, older drivers were more forgiving about false alarms when they understood the cause of the alarm (Eby et al., 2016).

Distraction caused by ADAS creates concern amongst older drivers. Older drivers reported that they are on alert for the possibility that they will be distracted by ADAS or that they have been distracted by ADAS (Musselwhite and Haddad, 2007). Distraction is considered a hindrance to safety (RICA, 2014). Navigation systems in particular pose a high risk for distraction (Trübswetter and Bengler, 2013); compared to six percent of younger drivers, ten percent of older drivers agreed or strongly agreed that navigation systems distract them too much (Jenness et al., 2008). As well, older drivers are more distracted by active voice control systems compared to younger drivers (Eby et al., 2016).

Older drivers are concerned about becoming reliant on ADAS but there is no evidence this happens. When asked about their views on using ADAS, older drivers reported concern that they, or other drivers, could become over-reliant on the systems (Musselwhite and Haddad, 2007). Because there is a lack of trust that ADAS will always alert drivers and carry out the appropriate actions, there is concern that over-reliance will lead to drivers failing to react or take control when necessary. (Marshall, Chrysler and Smith, 2014; RICA, 2014). Forward collision warnings were seen as the system that drivers are most likely to become over reliant on and night vision was seen as the least, with no difference between younger and older drivers (Marshall, Chrysler and Smith, 2014). Despite these concerns, there is limited evidence that drivers do become over-reliant on ADAS. Amongst drivers with parking sensors, rear-view cameras, navigation systems, and ACC, 60 percent reported that their usage of the

systems did not increase over time (Jenness et al., 2008). However, drivers with blind spot detection reported less frequent signal use (Eby et al., 2016). As well, drivers reported that after obtaining a vehicle with ADAS they did modify their driving routines, such as limiting shoulder-checking, braking, checking mirrors and looking for pedestrians, but replaced these routines with alternative safety checks, such as checking the blind spot monitor, viewing the rear-view cameras, and listening and reacting to signals emitted by e.g. pedestrian detection systems (Gish et al., 2017b). Concerns about over reliance do not appear to have come to fruition; the majority of older drivers believe that ADAS increase safety and believe that ADAS perform useful functions. No studies included in the review explicitly asked about over-reliance on ADAS, but no concerns around over-reliance were reported in studies of drivers who have experience using ADAS. As well, no studies included investigated whether pedestrians also have concerns about drivers becoming over-reliant on ADAS; this should be investigated because unsafe driving due to ADAS will have implications not only for drivers but other road users as well.

5 Discussion and conclusion

The objective of this review was to investigate (1) how ADAS is received and used by older drivers, (2) how this will impact the mobility of older people, and (3) what the implications of this are for delivering transport services over the next five to ten years. Because they are designed to simplify driving and increase driver safety, ADAS have been highlighted as potential technologies to meet the transport needs of the ageing population (Rhiu et al., 2015; Young and Bunce, 2011). ADAS can aid drivers by alerting them to dangers, assisting with driving manoeuvres, improving visibility, and taking control of the vehicle when necessary. The utility of these functions has led researchers to suggest that ADAS can increase the mobility of older drivers, delay driving cessation, and reduce depression, loneliness, and isolation amongst older drivers, particularly older drivers with declining physical and mental capabilities (Emmerson et al., 2013; Musselwhite and Shergold, 2013). Despite the potential for ADAS, there is also concern that older drivers will perceive, or find, that ADAS are difficult to use and that uptake amongst older drivers will be low (Eby and Molnar, 2012; Guo, Harvey and Edwards, 2017). More research is needed to understand when, how and why older drivers use ADAS and what they think of them.

5.1 Emerging themes

Through a systematic search and inclusion process, this review sought to explore the use of, and attitudes towards, ADAS amongst older drivers. By synthesising and comparing results across 23 studies, it has been possible to draw conclusions and clarify what is known, and what remains to be discovered, about the relationship between ADAS and older drivers. Five themes emerged in the review.

First, information and warning systems appear to be the most preferred form of ADAS amongst most (but not all) older drivers. The functions of ADAS can range from purely informative (e.g. navigation systems) to fully automatic (e.g. emergency braking systems). Starting with the desirability and willingness to use ADAS, there is a clear preference for information and warning systems. This is then reflected in the ownership rates and, more tellingly, frequency of use of different ADAS systems; information and warning systems are owned and used more frequently compared with automatic systems. This preference is also displayed in the after-use opinions of ADAS, with older drivers finding information and warning systems more acceptable compared with automatic systems. Studies about the perceptions of different types of ADAS provide insight into why information and warning systems are more preferred; there is a lack of trust amongst older drivers towards automatic systems because these systems are not perceived to be reliable, lead to increased safety or be as useful as information or warning systems. However, there is evidence that amongst older drivers with age-related impairments, automatic systems are perceived to be as trustworthy as their own capabilities and perceived as useful for overcoming the limitations they face. Therefore, amongst older adults generally, information and warning systems appear to possess the greatest potential for impacting the mobility and mode choice of older people, but amongst older adults with age-related impairments, automatic systems have greater potential.

Second, the perceptions older drivers have of ADAS before using them and the opinions they have of ADAS after using them, do not differ largely. The percentage of older adults who are willing to try ADAS is similar to the percentage of older adults who would like to use ADAS again: 80 percent and between 71-95 percent (depending on the specific system) respectively (Duncan et al., 2015; Jenness et al., 2008). As well, amongst older drivers without and with experience of ADAS, the

systems are valued for their utility to aid with driving and solve particular driving problems, such as visibility at night (Gish et al., 2017a; Guo et al., 2010). Where before-use perceptions and after-use opinions about ADAS differ the most relates to concerns about use of ADAS. Concerns about the reliability and ease of use of ADAS remain after experiencing ADAS but concerns around over-reliance appear to lessen after use. Even after using them, most older drivers do not trust automatic systems and navigation systems and believe that these types of ADAS can be difficult to use (Gish et al., 2017b; RICA, 2014). However, there is limited evidence that drivers remain concerned about over-reliance on ADAS after experiencing ADAS, and most drivers with ADAS experience do believe that ADAS increases safety (Eby et al., 2018; Gish et al., 2017a). Overall, these findings suggest that willingness to use ADAS does not change dramatically after experiencing ADAS, but the type of ADAS experienced plays an important role. Further, after experiencing ADAS, concerns about the systems may be somewhat mitigated as drivers learn how to use the systems and become more confident in their ability to increase safety.

The third key finding is that use and attitudes of ADAS amongst older drivers vary by gender. More older males own and use ADAS compared to older females and a higher percentage of older women have never learned to use ADAS compared to males (for example, in one study, six percent of older males had never learned to use ACC compared to 35 percent of older females), suggesting that older women may be more hesitant to use ADAS. However, ADAS may hold even more benefits for females; in one study more women reported that they would avoid going unfamiliar places and on dark roads if they did not have ADAS compared to older males. This is important knowledge because in the UK, even though the number of older female drivers is increasing and they are more likely to live alone, older women are still more likely to be reliant on men for vehicle access, are more likely to self-regulate or end their driving careers voluntarily, and are more negatively burdened by lack of transport alternatives than men (Shergold, Wilson and Parkhurst, 2016). Greater research is needed on the reasons for these differences and perhaps differentiated efforts are needed to encourage the use of ADAS amongst older male and female drivers.

Fourth, health is another factor that appears to influence the use and attitudes of ADAS amongst older drivers. As explained above, the presence of age-related impairments appears to moderate older drivers' acceptance of automatic ADAS, as drivers with sensory (such as poor vision), physical (such as reduced mobility) and mental (such as mild memory loss) impairments are more willing to use, and are more accepting of, automatic ADAS compared to older drivers without impairments. Because the percentage of adults over the age of 80 is increasing, and more importantly so is the number of drivers over the age of 80, the number of drivers experiencing cognitive and physical limitations is likely to increase (Musselwhite and Shergold, 2013). This means that automatic systems may begin to become more important for the continued mobility and safety of older drivers. Additionally, one study found that respondents with multiple health concerns indicated the highest likelihood of using ADAS compared to respondents with no health concerns; this is because ADAS is perceived as useful for mitigating vision and memory problems (Souders et al., 2017). Similarly, systems that help older drivers to see at night, reduce eye strain, or reduce the amount of times drivers have to turn their heads, are considered useful (Eby et al., 2018; Eby et al., 2016). These findings suggest that, if more older drivers with age-related impairments used ADAS, ADAS may hold potential for mitigating the effects of age-related impairments and declines in health on driving that occur with old age.

Fifth, there is a lack of studies on the actual impact of ADAS on the mobility of older adults. The potential for ADAS to increase the mobility and decrease the isolation, depression, and loneliness of older adults is covered substantially in the presently available literature (Eby et al., 2016; Guo et al., 2010); however, few studies

investigate whether and how ADAS *actually affects* these outcomes. In this review, only two studies (Eby et al., 2016; Jenness et al., 2008) report how owning ADAS influenced the time of day and roads older drivers drove on. Self-regulation of driving is a widely acknowledged phenomenon amongst older drivers, with evidence that older drivers gradually reduce driving by not going out at night or during rush-hour and avoiding difficult roadways because of concerns over decreasing abilities (Musselwhite and Shergold, 2013). Large surveys or experiments that measure the long-term effects of using ADAS are needed, particularly investigating whether ADAS increases overall driving frequency, if ADAS allows drivers to prolong driving, and whether ADAS allows older adults to be more mobile, leading to less isolation, depression, and loneliness. For example, a driving experiment could entail providing a group of older drivers with vehicles equipped with ADAS to drive with over a long time-period and compare the driving habits of this group to a control group without ADAS over the same period. This would provide a greater understanding of whether and how older drivers adjust their driving habits in response to having ADAS.

5.2 Limitations

The studies included in the review represent a small sample of the research on ADAS and older drivers. The purpose of this review was to synthesise the results of the highest quality, most recent, and most relevant studies available about older drivers' attitudes towards ADAS. Therefore, there are studies that were not included in the review that covered outcomes of interests and that would have possibly provided a greater understanding of the relationship between ADAS and older drivers. However, the validity of the findings and conclusions drawn in this review is not threatened by the decision to include only 23 studies. The studies included represent the best available evidence about ADAS and older drivers. Additionally, two systematic reviews that include over 300 studies combined were included amongst the 23 studies, thereby increasing the evidence base drawn on in the present review. The number of studies that cover a particular outcome in this review does not always reflect number of studies in total that have covered these outcomes. However, the number of studies in this report reflects that there are only a small number of high quality and recent studies that cover these topics.

The studies included in this review were chosen because they were deemed to be high quality and relevant to the research questions. However, there is a limit to the generalisation of the findings in this review. Most studies on ADAS use small, relatively heterogeneous samples due to study design and the demographics of ADAS users; many studies included in this review followed a qualitative design (in which sample sizes are small) or a survey design (in which samples are predominately white and middle-income). As well, the majority of the studies included in the review are based in the US where different brands and types of vehicles are available, meaning that the findings of American studies may not be generalizable to Britain. There is only one large, random-sample survey that investigates older adults' awareness of and usage of ADAS in England (Department for Transport, 2018). More representative surveys on older drivers' attitudes towards and experience with ADAS are needed before strong conclusions can be made. As well, in all studies except for three included in this review, older drivers are classified as one group. The recent survey on technology and transport in England (Department for Transport, 2018) shows that older drivers as a group differ greatly in their awareness level and rates of experience with ADAS (for example, awareness of ADAS drops from 77 percent amongst older drivers aged 55-64 to 53 percent amongst older drivers aged 75 and older); more research is needed on how attitudes towards ADAS vary by age within the cohort of older drivers.

5.3 Conclusion

Older drivers are receptive to, and accepting of, ADAS. Across types of ADAS, older drivers report a higher level of preference and acceptability of ADAS compared to younger drivers. There is also evidence that ADAS can increase the mobility of older drivers, by assisting drivers to drive on unfamiliar roads and at all times of the day and by lessening the effects of age-related impairments that hinder the driver ability of older drivers. There are however, concerns about ADAS and issues with usability that need to be addressed in order to make ADAS more appealing and useful for older drivers. First, ADAS are considered useful, to the extent that they remain easy to use and do not cause distractions. Second, some systems have a greater appeal than others, for example, communicating information audibly rather than visually. Third, as technologies become less expensive, more vehicles are being outfitted with ADAS, sometimes unbeknownst to drivers and subsequently owning a vehicle with ADAS does not guarantee that older drivers will use the systems (particularly women). By addressing these issues and building on the general acceptability of ADAS amongst older drivers, there is a role for ADAS in meeting the transport needs of older adults in the UK over the next five to ten years.

6 References

6.1 Background literature

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