The impact of visual impairment on road safety: Rapid evidence review

This report was completed in 2020 and does not cover literature published after that date

Prepared for: Department for Transport

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Background

On 19th July 2019 the UK Department for Transport published a refreshed road safety statement and 2-year action plan to address road safety issues throughout the lifetime of roads users, from babies to the elderly (Department for Transport, 2019). As outlined in this statement, more evidence is needed around the extent to which vision problems pose a road safety risk. While driving is understood to be a visual task, the evidence relating to the effect of impaired vision on road safety is complex and contradictory. As more people live longer there will be more people living with long-term health conditions and disabilities, including visual impairments. The full implications of the UK's ageing population remain underexamined in many areas.

There is substantial variation in visual standards for driving across EU member states. Most EU member state require testing of visual acuity and visual field by a medical doctor, ophthalmologist or optometrist. However, in Cyprus, France, the Netherlands, Norway and Great Britain, a number plate test is used (European Council of Optometry and Optics, 2017). There have been calls on the Department for Transport to introduce tougher eyesight testing requirements, but before it can be determined if this is required a better understanding of the extent to which vision problems pose a road safety risk in the UK is needed.

Objective

This review draws on a systematic process to explore the extent to which driver eyesight problems or visual impairments pose a risk to road safety in the UK.

Methods

The review took the form of a rapid evidence review (RER) – a tool for systematically finding and synthesising available research as comprehensively as possible within the constraints of a given timetable. Due to the need for a rapid and efficient review process, only a portion of the studies that met the inclusion criteria were synthesised in the report.

Search: A combined approach was used involving searching across academic databases, online websites and repositories, websites for transport ministries in countries of interest and forwards and backwards citation tracking of key literature.

Inclusion criteria: Studies were screened and assessed for inclusion in two stages against a number of inclusion criteria: at title and abstract, and at full text. There were both general inclusion and exclusion criteria and research question specific inclusion criteria. Included studies were published in 2000 or afterwards, came from both the academic and grey literature (unpublished) and included both visual impairments and road safety. The population of interest was drivers of a motor vehicle[a] (including cars, buses, lorries, motorcycles) and no limits were set on the types of participants in the studies included at the screening stage.

Studies could be either primary or secondary research and had to be in English or German. The studies could be either from the UK or a set of other countries with similar national vision standards for driving, including UK, Australia, Belgium, Canada, Denmark, Finland, France, Germany, Italy, Japan, Netherlands, Norway, Spain, Sweden, Switzerland and the USA. Due to the range of different research questions, we did not set limits on the type of outcome measures to be included at the screening stage. Relevant studies were also screened for inclusion against several research question specific criteria. These needed to examine; road traffic collision and casualty as an outcome; driving conditions (such as low light), driver characteristics or behaviour; non-visual conditions which moderate the relationship between visual impairment and risk of road traffic collision; and in specific instances be an intervention from the UK.

Results and study prioritisation: A total of 143 studies met our criteria for inclusion in the review. A set of prioritisation criteria were utilised to determine which of the studies that met our criteria should be prioritised for data extraction. The findings of the 41 prioritised studies were synthesised narratively. The prioritisation process was intended to ensure that evidence for all research questions was included in the review. The findings section and review conclusions are therefore based on a proportion of all includable studies and do not comprehensively summarise all potentially relevant evidence.

A large number of included studies were evidence reviews that cover multiple countries and intervention types. The final 41 studies included for synthesis included only a limited number of UK specific studies and these were complemented by international literature.

Conclusions

The only clear evidence on a link between a visual impairment and a higher rate of motor vehicle collisions was in relation to cataract. However, international evidence indicated that drivers with a visual impairment, in particular glaucoma, cataract and age-related macular degeneration, may choose to moderate their risk of motor vehicle collisions by changing their driving behaviour, such as avoiding driving at night. There was also some evidence that drivers compensate for their visual impairments by employing different patterns of eye movement and increased scanning behaviour.

There were three visual impairments identified for which there was some limited evidence of an association with increased risk of road traffic collision and which are not currently routinely tested for in the GB national vision standard for driving. These were impaired contrast sensitivity, visual field loss and age-related macular degeneration. Changes suggested to the existing GB national vision standards for driving included: introducing a measure of contrast sensitivity, a measure of visual field, and expanding the test for visual acuity to include both dynamic and static visual acuity. Age-based screening for licence renewal was not widely recommended. There was discussion on the relative validity of the tests for visual acuity, with several studies concluding that the Snellen chart is a poor measure of visual acuity and one study from the UK recommending the use of the ETDRS (Early Treatment Diabetic Retinopathy Study) test as a better alternative.

There was little evidence on an association between non-visual conditions, visual impairment and risk of collisions, though one recommendation from the U.S. suggested joint hearing and visual tests should be carried out. There was limited evidence presented that non-visual conditions could act as confounding factors in the relationship between vision and road safety, and that having multiple medical conditions increases the risk of road collisions.

There was no evidence among the prioritised papers on the number or proportion of visual impairments among drivers in the UK and there was mixed evidence on whether the risk of motor vehicle collision increases as drivers age. There was evidence from both evidence reviews and primary studies that the prevalence of certain visual impairments does increase with age, and that these visual impairments, such as cataract, age-related macular degeneration, glaucoma and diabetic retinopathy, may impact on driving performance or be associated with an increased risk of motor vehicle collision. Overall, the findings suggest that, although the risks related to driver visual impairment may increase with an ageing population, this risk could be somewhat reduced by employing countermeasures, such as changes to road design to increase driving safety and training for ageing drivers.

The conclusions drawn are taken from the 41 prioritised studies, and any gaps in the evidence discussed in this report may not necessarily be true across the entirety of the literature. A further review of the prioritised studies or a more systemic search for evidence against the secondary research questions may uncover further relevant research studies which could help add to the evidence base on the extent to which driver visual impairments pose a risk to road safety in the UK.

1 Introduction

On 19th July 2019 DfT published a refreshed road safety statement and 2-year action plan to address road safety issues throughout the lifetime of roads users, from babies to the elderly (DfT, 2019a). As outlined in this statement, more evidence is needed around the extent to which vision problems pose a road safety risk. There have been calls on the Department for Transport to introduce tougher eyesight testing requirements, but before it can be determined if this is required a better understanding of the extent to which vision problems pose a road safety risk in the UK is needed.

This rapid evidence review (RER) seeks to explore the relationship between visual impairment and road safety. While driving is understood to be a visual task, the evidence relating to the effect of impaired vision on road safety is complex and contradictory. This RER is an opportunity to bring together the evidence on this. This rapid evidence review was designed to efficiently locate and synthesis a body of relevant literature around six key research questions set out by the Department for Transport. Due to the need for a rapid and efficient review process, only a portion of the studies that met the inclusion criteria are synthesised in this report.

1.1 Background

The UK population is changing in both size and shape. Whilst the overall population is set to increase to 72.4 million by 2043, this is largely due to people living longer and immigration. Meanwhile, birth rates remain constant or in decline (ONS, 2019a). As a result, the population of the UK is ageing and is projected to continue to age. In 2018, one in five people were over 65. By 2050, one in four people in the UK will be over 65 (ONS, 2019b). There will also be a growth in the number of people aged 85 and over, with this projected to double in the next 25 years (ONS, 2019a).

As more people live longer this means there will be more people living with long-term health conditions and disabilities (ONS, 2018). The full implications of the UK's ageing population remain underexamined in many areas. For instance, the effect on road safety of an increasing number of older drivers living with long term health conditions is relatively unclear.

1.2 Driving and ageing

Almost 41 million people in the UK hold a full driving licence, equivalent to 76 per cent of the adult population. Of this, 13% are aged 70 and over and 1% are aged over 85 (DfT, 2019b). Both the proportion, and the total number, of people aged 70 and over with a full driving licence has increased over time in both England and Scotland. National Travel Survey (NTS) statistics for England show an increase in the percentage of people over 60 who hold a full driving license from 63% in 2007 to 72% in 2017. The 1998/2002[b] NTS statistics for Scotland showed that 33% of those aged 70 and over held full driving licences, increasing to 52% in the 2008/2012 data (DfT 2020). The

Driver and Vehicle Licensing Agency (DVLA) maintains the registration and licensing of drivers in Great Britain but not in Northern Ireland.[c]

People aged 60 and over are the group most likely to own a car or motor vehicle: 77% of this age group own their own car compared with 76% of 30-59 year olds and 55% of 18-29 year olds (Statista, 2017). Research also demonstrates a sustained decline in car usage among young people suggesting that future road use will be composed of a greater proportion of older drivers (Chatterjee et al, 2018). Evidence suggests that there have been increases in travel among some older groups both in terms of trips per person, per year and in terms of miles per person per year. Between 2003 and 2010, across all age groups there has been a decline in both measures over time. After 2010, older people began to travel more, while the amount of travel for other age groups continued to decline (DfT analysis of National Travel Survey data, 2020).

Older drivers have among the highest rates of killed or seriously injured road collisions (KSIs), second only to young drivers aged 17 to 24. Drivers aged 75 to 79 have 56 KSIs per billion miles travelled, drivers aged 80 to 84 have 94 KSIs per billion miles travelled and drivers aged 85 and over have 174 KSIs per billion miles travelled. In comparison, young drivers aged 17 to 24 have 98 KSIs per billion miles travelled. Drivers aged 80 and over have the highest fatality rates of any age group, with 9.8 driver fatalities per billion miles travelled in those aged 80 to 84 and 31.4 driver fatalities per billion miles travelled in those aged 85 and over (DfT analysis of National Travel Survey data, 2019).

Driving requires effective visual, motor and cognitive skills. Drivers are required to concentrate under different conditions, from sunlight which causes glare to twilight and darkness at night (Older Drivers Task Force, 2016). This becomes more challenging with age, as the eye's adaptation to changes in luminance slows and its optics scatter light more (Owsley, 2016). There is also a decrease in the highest possible level of visual acuity.[d] In addition, older people are more susceptible to ocular diseases such as cataracts and glaucoma, which may impact on their ability to drive safely (Owsley et al, 1999; Lee et al, 2017).

1.3 Eyesight in UK driving legislation

There is substantial variation in visual standards for driving across EU member states. Most EU member state require testing of visual acuity and visual field by a medical doctor, ophthalmologist or optometrist. However, in the UK, as in some other European countries,[e] there are no requirements for eyecare professionals to undertake visual tests on drivers during routine sight tests or at licence renewal (European Council of Optometry and Optics, 2017).

Whilst other countries, such as the Republic of Ireland, require evidence of visual acuity from an eyecare professional, in the UK vision is tested at the beginning of the practical driving test by the driving test assessor based on an individual's ability to read the number plate of a vehicle from 20 metres (Optometry Today, 2018). Similarly, in Cyprus, France, the Netherlands and Norway, a number plate test is used.

In 2009, the European Commission (EC) implemented a directive which attempted to standardise the requirements for driving tests across the European Union. The annex of the directive stipulates that drivers should: 'undergo an appropriate investigation to ensure that they have adequate visual acuity' (EC 2009, p.2). They must demonstrate a minimum of 0.5 decimal acuity, adequate field of vision, good contrast sensitivity, twilight vision and no visually problematic glare. Member States were given until 2013 to demonstrate compliance. The UK Department for Transport (DfT) responded to this by adding the need to achieve 0.5 decimal acuity and the number plate test to the legal text (DfT 2013, p.21).

1.4 Road casualties in Great Britain

Since 2010, the overall number of fatalities and serious injuries from road collisions has been largely stable (DfT, 2019c). This has been a trend across the EU as a whole with the number of road fatalities across Europe plateauing around 2013 (European Transport Safety Council, 2019). That said, Britain has comparatively fewer road deaths per million inhabitants, bettered only by Switzerland and Norway (DfT, 2019c). In 2018, Britain experienced a total of 160,597 casualties of all severities reported (DfT, 2019c). Of this, there were 25,511 serious injuries and a further 1,784 deaths due to road accidents.

1.5 Why it is important to do the review

Although driving is clearly a visual task, there remains a need for strong evidence for what visual acuity level is needed for 'safe driving.' This has implications for policymaking, particularly in the context of an ageing driving population. Ensuring that everyone is safe on the road is paramount for future policy in this area. More evidence is therefore needed to demonstrate the extent to which visual impairments/declining visual functions pose a risk to road safety for drivers of all ages, as well as to establish a necessary threshold for visual acuity, visual field and other visual functionality standards and safe driving.

1.6 Aims of the rapid evidence review

The core objective of the RER is to understand the extent to which driver eyesight problems or visual impairments pose a risk to road safety in the UK. The specific research questions for this rapid evidence review are given below. The search strategy was designed explicitly to retrieve evidence relevant to the primary research questions (research questions 1, 2 and 3). Where evidence relevant to the secondary research questions (research questions 4, 5 and 6) was located, it has also been included.

Primary research questions:

1. What is the relationship between driver visual impairment and risk of road traffic collision or casualty[f] in the UK?

a. What evidence is there of the association between driver visual impairment and risk of road traffic collision or casualty in the UK?

b. To what extent do certain driving conditions (such as low light), driver characteristics or behaviour moderate the risk of UK road traffic collision or casualty involving drivers with visual impairment? How does this vary across different types of driver visual impairment?

c. Is there evidence that the relationship between visual impairment and risk of road traffic collision or casualty is different in the UK than it is in other countries with different eyesight testing regimes?

2. What is the most recent evidence regarding the number of UK drivers who have visual impairments?

    a. What evidence is there regarding the proportion of drivers with a visual impairment who meet (or fail to meet) national vision standards for driving (in terms of both acuity and field of vision)[g] or pass the 'number plate test'?

    b. What evidence is there regarding the proportion of drivers with a visual impairment who meet the national vision standards for driving in relation to visual acuity only and pass the number plate test but do not have an adequate field of vision?

    c. Is there evidence of the proportion of such drivers that have declared their condition to DVLA?

3. Are there driver visual impairments that are positively associated with risk of road traffic collision or casualty that cannot be identified via testing processes such as national vision standards for driving or the 'number plate test'?

Secondary research questions:

4. Is there evidence to support revisions to the UK driving eyesight rules or eyesight testing regime for drivers?

    a. If so, what does the literature suggest that such a regime could include?

5. What other non-visual conditions (e.g. head and neck mobility or cognitive impairments) moderate the relationship between visual impairment and risk of road traffic collision or casualty, and how?

    a. Is there evidence to support revised or amended eyesight requirements for drivers who also have other non-visual conditions?

6. Is there any evidence to indicate that risks related to driver visual impairment may increase with an ageing population?

a. Is there evidence that the prevalence of visual impairments in the UK population (and UK population of drivers) is changing? How does this prevalence rate vary by age-group and visual impairment type?

b. Is there evidence that the prevalence of people with both visual impairments and other non-visual conditions in UK populations (and UK population of drivers) is changing? How does this prevalence rate vary by age-group and visual impairment type?

2 Methodology

For this rapid evidence review, a combined approach was used which involved searching across academic databases, online websites and repositories, websites for transport ministries in countries of interest, and citation tracking. Studies were screened and assessed for inclusion in two stages against a number of inclusion criteria: at title and abstract, and at full text. Studies which were included at full text screening were rated against a number of prioritisation criteria and data was extracted for the top-rated studies. The data extracted was synthesised narratively and findings are structured by research question.

2.1 Search strategy

2.1.1 Search of academic databases

The academic databases listed in Table 2.1 were searched using the search string given in Appendix 1 between the 4th and 12th November 2019. The search string was developed in collaboration with a search specialist and with guidance from the Secretary of State for Transport's Honorary Medical Advisory Panel on driving and visual disorders (here after known as the Vision Panel). The search string was piloted on a single database to refine the search string. The piloting of the search string identified a limited number of hits from the UK, so the search string was expanded to include additional countries of interest. The search string was then used to search across four different academic databases.

Table 2.1 Academic databases searched using the search string
Medline
Embase
Scopus/Web of Science
EBSCO Discovery Service

2.1.2 Search of websites and repositories

The following websites, repositories, and websites for transport ministries in countries of interest listed in Appendix 2 and 3 were searched using a simplified version of the search string to identify any grey or unpublished literature relevant to the research questions.

2.1.3 Citation tracking

Backwards and forwards citation tracking was carried out on all papers, which met the inclusion criteria at full text screening, to identify possible sources of further relevant literature. Backwards citation tracking was conducted by assessing the studies cited by each source and forward citation tracking was conducted by searching Google Scholar and academic databases to identify further studies which had cited each source.

2.1.4 Duplicates

As the search process used a wide range of different databases, repositories and websites, it was likely that the same studies would have been found through more than one source. In order to deal with this, the final stage of the search process was to remove any duplicates from the full list of all studies that were found, before the screening processes commenced. This was achieved by running a search for duplicates based on article titles. Any further duplicates where identified during the first stage of screening.

2.2 Screening

2.2.1 Piloting screening process

Before each stage of the screening process commenced, the screening tools were tested and piloted by the research team to promote inter-screener reliability. All screeners screened the same small sample of search results then met to discuss any difference in inclusion decisions and questions which arose from the screening process.

2.2.2 Screening processes

Studies were screened and assessed for inclusion in two stages, at title and abstract and at full text. A single screener reviewed each search result against inclusion criteria at title and abstract stage using Abstrakr, a systematic review screening tool. Studies which appeared relevant were included for full text review. At full text stage, studies identified for inclusion were checked by a second reviewer.

Inclusion and exclusion criteria

At title and abstract, and full text screening stages, search results were assessed against general inclusion/exclusion criteria and research question specific inclusion criteria.

The general inclusion and exclusion criteria that were applied to all six research questions are shown below in Table 2.2.

Table 2.2 General inclusion and exclusion criteria

Criteria	Inclusion	Exclusion
Language	English or German	Any other language
Publication status	Journal articles Unpublished and grey literature	Editorials Opinion pieces
Date of publication	2000 – present	Pre 2000[h]
Topic	Visual impairment and road safety. For the purposes of this RER, visual impairment is considered to be any loss of vision which cannot be corrected by glasses or contact lenses (NHS 2017). While not specified in the search terms, specific conditions of interest include glaucoma, diabetes, retinitis pigmentosa, stroke including hemianopia, cerebral tumour, arteriovenous malformation (AVM) and diplopia.	Studies in which visual impairment is not one of the health conditions included.
Population	Drivers of a motor vehicle[i] (including cars, buses, lorries, motorcycles)	Studies that do not report on drivers of a motor vehicle (including cars, buses, lorries, motorcycles)
Study design	Primary or secondary research studies with methodologies which appropriately answer the research questions.	Articles which do not draw on an appropriate methodology such as opinion pieces and editorials.
Participants	Due to the range of types of studies which may be included in this review, including computer modelling and simulation of the impacts of different eye conditions, there were no limits set on the types of participants in the studies included at the screening stage.	
Outcome measures	Due to the range of different research questions, we did not set limits on the type of outcome measures to be included at the screening stage.	

In addition to the general inclusion criteria, which were applied to all research questions, there were several research questions that had specific inclusion criteria. These are set out in Table 2.3 below:

Table 2.3 Specific inclusion criteria		
Criteria	**Inclusion**	**Research questions applicable**
Outcome measures	• Road traffic collision and casualty. Where possible, we have reported relative risk of collision/casualty (e.g. per billion vehicle miles or similar). • Where included papers report rates of collision/casualty and visual impairment without reference to the relative risk of collision, this is stated in the text. • Papers referring to observational studies using on-road or simulator tests which discuss the impact of visual impairments on factors related to risk of collision or casualty are included.	1, 3 and 5
Country contexts	UK, Australia, Belgium, Canada, Denmark, Finland, France, Germany, Italy, Japan, Netherlands, Norway, Spain, Sweden, Switzerland, USA.	1, 3, 4, 5 and 6
	UK only	2
Topic	Driving conditions (such as low light), driver characteristics or behaviour which moderate the risk of UK road traffic collision or casualty which also involve drivers with visual impairment.[j]	1 (b)
Topic	Non-visual conditions. For the purposes of this RER this meant any other impairment which is not connected to the loss of vision. While not specified in the search terms, non-visual conditions of interest include cognitive impairments and head and neck mobility.	5

2.3 Prioritisation

The number of studies which were included after the two screening stages set out above were then further reduced by using a prioritisation process. It was not within the scope of this rapid evidence review to synthesis evidence from all 143 studies which were included at full text screening. A full bibliography of all studies which were included at full text screening is given in Appendix 4. The most relevant studies were selected for data extraction through the prioritisation process whereby studies were assessed against seven prioritisation criteria using a prioritisation tool which assigned each paper a score (see Appendix 5).

The criteria for assessing priority of the studies were as follows:

- **Relevance to the research questions** - studies which provided evidence relevant to more than one research question were prioritised
- **Coverage** - studies which drew on multiple evidence sources, such as systematic or other evidence reviews, were prioritised
- **Date of publication** – studies which have been published since 2010 were prioritised
- **Context** - UK-based studies were prioritised
- **Methodology** – studies which used systematic searching or quantitative methodologies were prioritised over qualitative methodologies such as interviews and focus groups
- **Participants** – studies where older adults were participants were prioritised over studies where younger people or professional drivers were participants. For the purposes of this rapid evidence review, older adults refers to adults aged 60 or over. Where studies use their own classification for older adults, this will be reported where it differs from adults aged 60 or over.
- **Outcome measures** – studies which address the relative risk of road collision or casualty, rather than reporting rates, were prioritised.

2.4 Data extraction

Data extraction was undertaken for the most relevant studies prioritised for synthesis using a standardised extraction template (see Appendix 6). The data extraction tool included basic descriptive information relating to the included studies, any findings relevant to the research questions and an assessment of the quality of the evidence using the Weight of Evidence tool (see Appendix 7). The Weight of Evidence tool provides a framework for assessing the quality of the evidence and its relevance to the topic. Articles are scored high, medium, medium/low, or low across three domains (quality assessment, methodology and relevance) and assigned a final score which weights each domain equally (Gough, 2007).

2.5 Synthesis

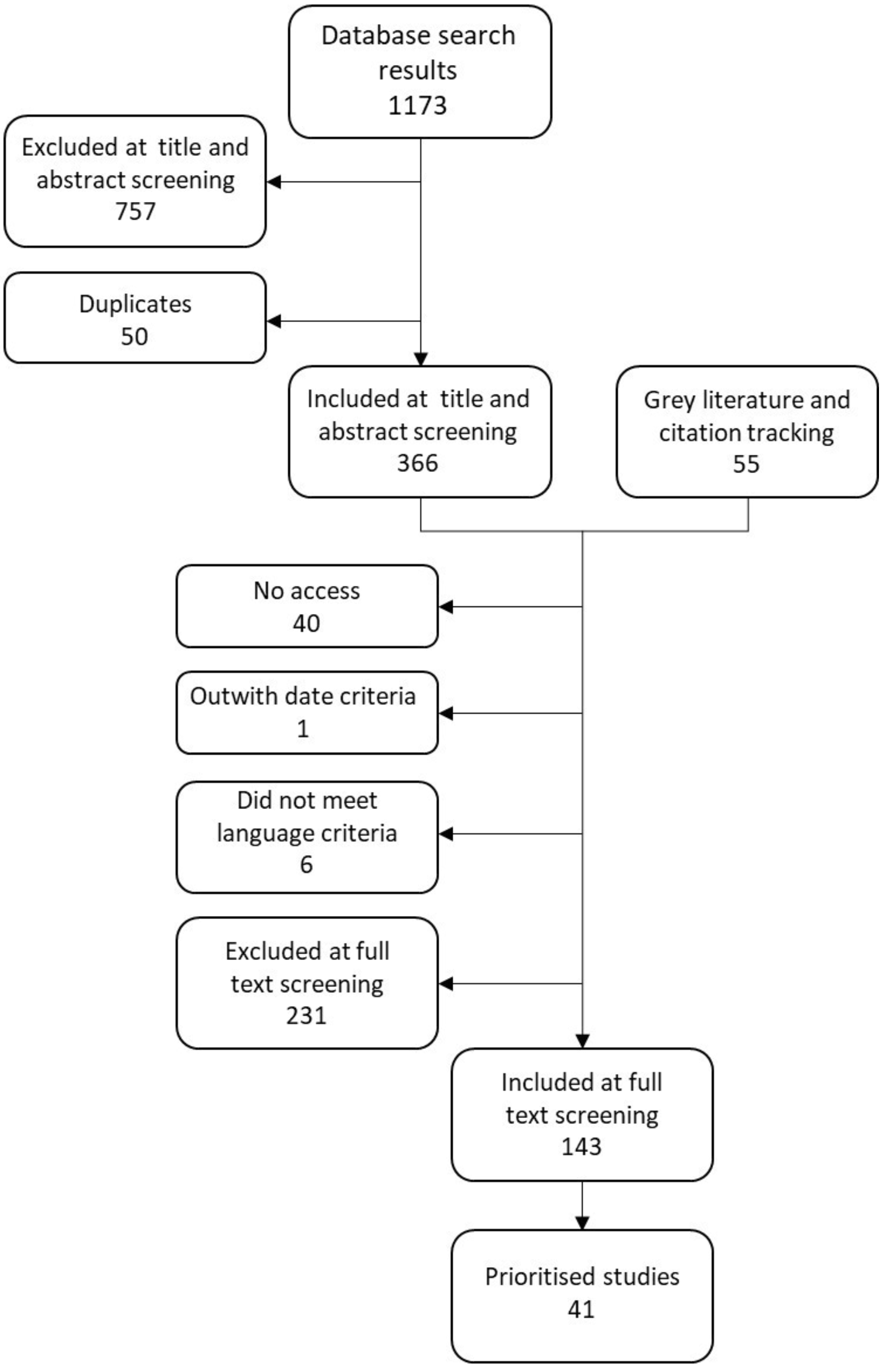
The data extracted from the prioritised studies was synthesised by research question. The findings provide a narrative synthesis of studies providing evidence which contributes towards answering each research question. Further substructure of the synthesis was led by themes or categories arising from the data. Many of the studies prioritised in this review were evidence reviews and provide evidence which is relevant to more than one research questions. Therefore, evidence from some studies is presented under multiple research questions.

3 Results

3.1 Search results

The PRISMA flowchart shown in Figure 3.1 below summarises the screening and inclusion processes and the number of studies included, and excluded, at each stage.

Figure 3.1 PRISMA Chart – screening and inclusion process



A total of 1173 results were retrieved from searches of academic databases. Following de-duplication and screening at title and abstract, 807 studies were rejected as they did not meet the inclusion criteria or were duplicates. The remaining 366 studies were screened using the full text and a further 278 were rejected, leaving 88 studies which were includable at full text screening. A further 19 results from searches of online repositories and websites were included and 36 results were retrieved from citation tracking. These 143 studies were assessed using the prioritisation criteria outlined in Section 2.3 above. Forty-one studies were assigned a prioritisation score of 4 or more. These 41 prioritised studies then went through the data extraction and synthesis process and are reported on in Chapter 4 below.

3.2 Coverage of research questions

The number of studies which provided evidence for each of the research questions is given in Table 3.1 below. Studies may appear more than once in the table below as they provide evidence relating to more than one research question. Most evidence was found relating to research questions 1 and 4, while relatively few papers were identified which related to research questions 2, 3, 5 and 6.

Table 3.1 Number of included studies which provide evidence relating to each research question	
Research question	Number of studies
1. What is the relationship between driver visual impairment and risk of road traffic collision or casualty in the UK?	25
2. What is the most recent evidence regarding the number of UK drivers who have visual impairments?	3
3. Are there driver visual impairments that are positively associated with risk of road traffic collision or casualty that cannot be identified via testing processes such as national vision standards for driving or the 'number plate test'?	5
4. Is there evidence to support revisions to the UK driving eyesight rules or eyesight testing regime for drivers?	21
5. What other non-visual conditions (e.g. head and neck mobility or cognitive impairments) moderate the relationship between visual impairment and risk of road traffic collision or casualty, and how?	3
6. Is there any evidence to indicate that risks related to driver visual impairment may increase with an ageing population?	9

3.3 Weight of evidence

Twenty-two of the prioritised studies were primary studies and nineteen were evidence reviews. All prioritised studies were assessed as being of high, medium or low quality using a Weight of Evidence tool (Gough 2007) (see Appendix 7). Ten of the primary studies and seven of the reviews were categorised as high quality. Evidence reviews which included details of search strings, databases searched, and inclusion criteria were rated as being of the highest quality while literature reviews which did not include search methodologies were rated as lower quality.

Table 3.2 Type of study by Weight of Evidence rating					
Type of study	Total	High	Medium	Medium-low	Low
Evidence review	19	7	6	2	4
Primary study	22	12	8	2	0

3.4 Availability of evidence from the UK

Assessing the availability of UK evidence on visual impairment and road safety was of particular interest for this rapid evidence review. Of the prioritised papers, only 2 evidence reviews, and 3 primary studies presented evidence from the UK. The greatest number of primary studies presented evidence from the USA (11), with a smaller number of studies from Japan (3), Australia (2) and Canada (1). Only two of the primary studies presented data from more than one country. However, the majority of evidence reviews included published evidence from multiple countries, 15 in total.

Table 3.3 Number and type of study by country		
	Evidence review	Primary study
United Kingdom	2	3
USA	2	11
Japan	-	3
Australia	-	2
Canada	-	1
Multi-country	15	2

3.5 Coverage of eye conditions

As described within the inclusion criteria set out in Table 2.5 above, for the purposes of this RER, visual impairment is considered to be any loss of vision which cannot be corrected by glasses or contact lenses (NHS 2017). Therefore, when the report refers to visual impairments, it is referring to a range of eye conditions that may affect a person’s ability to drive but excludes correctable levels of visual acuity.

A description of each of the main eye conditions that are mentioned in the 41 prioritised studies are detailed in Appendix 9.

3.6 Measures of road safety and risk of road traffic collision or casualty

The research discussed in both the evidence reviews and primary studies use a wide range of different methodologies and ways of measuring road safety and risk of road traffic collisions or casualties. It is not possible to produce a statistical meta-analysis[k] from this data as there are not sufficient numbers of similar studies, using the same methodology and outcome measures, to make robust comparisons between studies. The findings (see Section 4) are instead reported as a narrative synthesis.

In general, the relationship between visual impairment and driving is explored either through measures for driver safety or driver performance. This is described fully in Section 4.1 below. The 41 prioritised studies used a range of methodologies to assess the relationship between visual impairment and driver safety and performance. These are outlined below, along with some limitations of these methodologies:

- Population cohort studies – data is gathered from a defined population over time to identify outcomes (e.g. motor vehicle collisions) associated with exposure to particular conditions of interest (e.g. visual impairment). Cohort studies can be retrospective (e.g. participants report how many crashes they have been involved in over a defined period preceding the study) or prospective (e.g. participants are engaged in the study over a number of years and report changes to their driving habits over several waves of data collection). There are limitations associated with population cohort studies. There is the potential for under-reporting of road collisions and casualties, which applies to both self-reported collisions (as participants may under-report motor vehicle collisions) and police-reported collisions (as typically only injury collisions have to be reported to the police and so there is an under-reporting of minor injury collisions). In addition, there are inconsistencies in the definition of visual impairment, the seriousness of the condition and the way in which visual impairments are defined and diagnosed. As research participants are commonly recruited into research studies through their attendance for treatment at clinics and eye hospitals, their visual impairment may be more advanced and more likely to affect their driving compared with a driver who has a milder or less advanced visual impairment. Particularly for population cohort studies in older adults, limitations exist in recruiting comparable control groups without introducing additional confounding factors such as comorbidities.

- Secondary analysis – analysis of data collection by agencies such as the police, driving licensing authorities and insurance companies to identify rates of motor vehicle collisions. This method may be limited by inconsistencies in the quality of data collected by other parties.

- On-road or closed road driving observation – driving performance can be assessed by a driving evaluator or researcher against a number of criteria or using vehicle-mounted cameras and sensors. This method can be used to explore differences in driving performance between groups (e.g. drivers with visual impairment vs drivers with normal vision) or compensatory behaviour displayed by drivers with visual impairment. Changes to driving performance as a result of visual impairment may also be assessed through the use of goggles which simulate the effect of visual impairment. Limitations associated with driving observation include drivers potentially modifying their driving during the observation, drivers being observed over a brief period of time which may not be representative of their normal driving performance, and the limited association between driving performance and driver safety identified from the literature.

- Simulator studies – driving performance can be assessed using driving simulators, which can range in design from desktop mounted systems with a single monitor to large immersive systems capable of replicating a realistic driving experience. Driving simulators allow for consistency across testing scenarios but can cause simulator sickness in some individuals. However, there is a lack of evidence of association between simulator driving performance and driver safety.

3.7 Limitations in the review process

This review took a systematic approach using an adapted rapid evidence review methodology which was designed to efficiently locate and synthesis a body of relevant literature. The research questions had a broad focus across several aspects of visual impairment and driving. Due to the need for an efficient review process, we only synthesised a proportion of the studies meeting our inclusion criteria. The findings section and review conclusions are therefore based on a proportion of all includable studies and do not comprehensively summarise all relevant evidence. Studies were prioritised for synthesis based on relevance (see section on methodology). A full list of studies meeting inclusion criteria but not synthesised is provided in Appendix 4. As this is not a systematic review, we cannot claim that this review represents the totality of evidence regarding the topic of interest.

The search string was designed to locate evidence which would be relevant to the primary research questions (research questions 1, 2 and 3). While any evidence which was relevant to the secondary research questions (4, 5 and 6) has been included in this review, it may be that additional evidence would be found for the secondary research questions through a search string more targeted towards answering these specifically. Inclusion decisions at title and abstract were undertaken by a single reviewer, meaning that it is possible that some relevant studies may have been missed.

Evidence from the UK was of particular interest for this review. Despite prioritising studies which contained data from for the UK for inclusion, only five papers which presented data from the UK were included in the review. There appears to be relatively little relevant evidence from the UK regarding visual impairment and driving but, as this is a rapid evidence review, it was not possible to draw a definitive conclusion regarding the size and strength of the evidence base.

Nineteen reviews were included in the prioritised studies. The findings from these reviews are summarised at review level, and therefore it is not always possible to comment on the methodology used or the quality of the studies from which the findings were drawn. As reviews which were published within the date criteria (2000 onwards) may include evidence from studies published before 2000, some findings reported in the review may be based on older data. In addition, it is not always possible to identify the country of origin of the evidence included in reviews, meaning that some findings may be drawn from countries not listed in the inclusion criteria. Where the country is known from the review, this is included in the report.

The wide range of methodologies used in the prioritised papers to assess elements of driver safety and driver performance means that it has not been possible to compare or combine results from different studies to draw an overall conclusion. Therefore, the included studies have been described narratively.

4 Findings

This section includes narrative summaries of the findings drawn from the 41 prioritised studies. To ensure that all relevant data from the 41 studies is used to answer each of the six research questions, this section includes six sub-sections; one for each of the research questions being addressed by this rapid evidence review. Descriptive tables on the coverage of research questions, methodology, country and weight of evidence are provided in Appendix 10.

Note that some connected topics may appear in multiple sections; for example, the relationship between ageing, visual impairment prevalence and the risk of road traffic collision is of relevance to both research question 1 (the relationship between driver visual impairment and risk of road traffic collision) and research question 4 (evidence to support revisions to the UK driving eyesight rules).

Within each sub-section, in general, we report studies in the following order: the UK data, where it is available, is presented first followed by the international evidence. The evidence reviews are then discussed first, from highest to lowest quality, followed by the primary studies.

We provide an indication of evidence review quality in the descriptive table in Appendix 10. Evidence reviews are labelled as systematic reviews, REAs, rapid reviews, literature reviews or evidence reviews. Typically (though not always) systematic reviews can be thought of as the most rigorous and literature reviews as the least rigorous of these evidence review methodologies. For quantitative primary studies, we report study design, as described by the study author, in the descriptive table Appendix 10, as an indication of study quality.

4.1 The relationship between driver visual impairment and risk of road traffic collision or casualty

Research question 1: summary of findings

Very little evidence was found from the UK regarding visual impairment and the risk of road collision or casualty. The evidence from included studies did not support a statistically significant link between visual acuity and motor vehicle collisions and there was a lack of agreement in the included literature as to the impact of impaired contrast sensitivity or visual field. There was some indication that the type and extent of visual field impairment may have an effect. There was general agreement across the included literature that cataract is associated with a significantly higher rate of motor vehicle collisions but the evidence regarding the impact of glaucoma and macular degeneration on driver safety was mixed.

Very little evidence was found from the UK regarding the extent to which driving conditions, driver characteristics or behaviour moderate the risk of road traffic collision or casualty involving drivers with visual impairment. Some evidence was found in the included studies that the risk of road collision or casualty is moderated by drivers' self-restriction such as not driving at right, reducing speed and distance, particularly in drivers with glaucoma, cataract and age-related macular degeneration. Compensatory mechanisms such as different patterns of eye movement, particularly in drivers with glaucoma and visual field loss and treatment for visual impairment, particularly cataract surgery, may also moderate risk of collision.

The first primary research question explored as part of this rapid evidence review was the relationship between driver visual impairment and the risk of road collision or casualty in the UK. The availability of UK evidence regarding visual impairment and the risk of road collision was explored, as was the extent to which driving conditions, driver characteristics and driver behaviour moderate the relationship between visual impairment and risk of road collision or casualty. Evidence of differences in the relationship between visual impairment and road traffic risk across countries was also investigated.

As discussed in Section 3.4 above, there was limited evidence from the UK contained within the 41 prioritised studies. This section presents evidence from other countries included within the search criteria, but it has not been possible to draw comparisons between the risks inferred by visual impairment in the UK and other countries with different testing regimes due to the limited availability of data from the UK.

Twenty-five studies included in this review provided evidence relevant to this research question. Twelve of these were evidence reviews and 13 were primary studies. The evidence is presented by condition, meaning that studies which provide evidence regarding more than one condition are cited multiple times. Where evidence from the UK is available, this is highlighted.

While not specified in the search terms, specific conditions of interest for this review included glaucoma, diabetes, retinitis pigmentosa, stroke including hemianopia, cerebral tumour, arteriovenous malformation and diplopia. Of these, a substantial body of evidence was found within the included studies for glaucoma and a small amount of evidence was found regarding diabetes and retinitis pigmentosa. Evidence relating to hemianopia is included but not in relation to stroke as this condition was not mentioned in any of the included studies. No evidence regarding cerebral tumour, arteriovenous malformation or diplopia was found in the included studies.

Owsley and McGwin's review (2010) provided an overview of the approaches taken in the literature to assessing the relationship between visual impairment and driving. In general, the impact of visual impairment on driving is described in one of two ways; driver safety and driver performance. Measures of driver safety are often expressed as rates of motor vehicle collisions per miles driven or per person years of driving. However, these measures can differ in the severity of collision (all collisions or only collisions which result in fatalities) and attribution (all collisions or only collisions in which the driver was at fault). Motor vehicle collisions can be self-reported or determined using police or insurance records. There are limitations associated with both of these methods of determining motor vehicle collision rates, as drivers are likely to underestimate or under-report the number of collisions in which they were involved, and not all collisions are reported to the police or insurance agencies.

When determining the difference in driver safety between a group of interest and a reference group (e.g. drivers with a visual impairment compared with a control group of drivers with normal vision) risk ratios, rate ratios or odds ratios may be used. Where available, we have included the risk, rate or odds ratio in the text. However, due to the inclusion of reviews in the prioritised studies, these are not always available as reviews may report findings without including statistics by which they can be evidenced.

Driver performance relates to driver behaviour when operating a motor vehicle and can be assessed through physical measures such as speed, breaking and position in lane, or by observation by a trained evaluator who rides in the vehicle and gives ratings on a variety of aspects of driving on an on-road or closed road course. While it seems logical that unsafe driver behaviour would be linked to increased risk of collision, Owsley and McGwin (2010) found little empirical evidence to support this. The authors suggest that the difficulty in demonstrating a link between driving performance and driving safety may, in part, be due to the assessment of driver performance in a brief snapshot and in an artificial setting which is not reflective of normal driving, whereas driver safety is estimated over many person-miles or person-years of driving.

Due to the range of different measurements and methods used in assessing the impact of visual impairments on driving, it has not been possible to conduct a statistical meta-analysis on the data drawn from the prioritised studies. Therefore, the findings from the prioritised papers are described narratively. For each visual impairment, evidence relating to driver safety, including rates and risks of motor vehicle collision, is presented first, followed by evidence relating to driver performance. Finally, any findings which relate to additional factors which may impact on the relationship between the visual impairment and driving are described, including compensatory mechanisms, driver self-regulation, licence restriction, driving conditions and treatment for the visual impairment.

4.1.1 Visual acuity

Visual acuity is a measure of the ability of the eye to distinguish shapes and the details of objects at a given distance. Loss of visual acuity would not generally be considered as a visual impairment under the definition used in this review as, in the majority of cases, visual acuity defects can be corrected through the use of glasses or contact lenses. However, visual acuity is the aspect of the GB national vision standards for driving which is tested during the driving test. In addition, a reduction in visual acuity may be the first indicator that sight is deteriorating, particularly for older drivers.

In general, the evidence prioritised in this review found little support for a statistically significant relationship between visual acuity and risk of motor vehicle collision or driver performance (Noyce, 2017; Huisingh et al, 2017; Sandin and Strand, 2016; Road Safety Observatory, 2013; Owsley and McGwin, 2010; Kotecha et al, 2008).

Both Sandin and Strand (2016) and Owsley and McGwin (2010) concluded that, if there is an association between visual acuity and driver safety, it is weak. Owsley and McGwin (2010) cited several studies which showed mixed results regarding whether visual acuity is associated with increased risk of motor vehicle collisions and highlight two large scale cohort studies, conducted in 2007 and 2009, which failed to find a statistically significant association. This finding was echoed by Kotecha et al in their evidence review of 2008. However, the U.S Department of Transportation's (2005) review of the literature from 1960 to 2000 suggested that dynamic visual acuity[l] is a reliable predictor of motor vehicle collisions.

The Owsley and McGwin (2010) review also looked at the use of bioptic telescopes (BTS) to manage visual acuity impairment, which is allowed by 35 US states and the Netherlands but not currently allowed in Britain. BTS are telescopes mounted in the superior part of the regular lens which incorporates the refractive correction. BTS users use the BTS to view signs, traffic and potential obstacles. They found that the evidence regarding the effectiveness of these is mixed. Four separate studies from different US states all reached the same conclusion that BTS users have a higher risk of collision than the control groups.[m]

A primary population-based study of older drivers aged 70 or over in Alabama, U.S. examined the association between visual and hearing impairment and motor vehicle collision involvement in older drivers (Green et al, 2013). The authors found that drivers with visual acuity impairment alone were not statistically significantly more likely than drivers without a visual acuity or hearing impairment to have been involved in a motor vehicle collision in the last 5 years. However, drivers with a combination of visual acuity and hearing deficits were nearly 1.5 times as likely to have been involved in a motor vehicle collision in the past 5 years (rate ratio = 1.52, 95% confidence interval = 1.01–2.30).

Owsley and McGwin argued that evidence indicating that visually impaired drivers tend to drive less, and in more familiar environments, could mean that any additional risk conferred by low visual acuity is diminished by drivers' self-regulating behaviours. The authors' suggestions that visual acuity testing does not measure the visual skills necessary for the safe operation of a motor vehicle, and that the relationship between visual acuity and road safety cannot be understood without the consideration of other visual factors, are discussed below.

4.1.2 Unilateral visual impairment and monocular vision

Unilateral visual impairment refers to visual impairment which is present in one eye, while monocular vision is sight loss in one eye. The prioritised literature found limited evidence regarding driver safety and monocularity (see Appendix 9 for details), and this literature tended to primarily concern commercial drivers. The visual standards for personal driving tend to be based on visual acuity using both eyes or the better eye. Reviews by both Owsley and McGwin (2010) and the Road Safety Observatory (2013) presented limited evidence from the 1980s on commercial drivers which showed mixed results as to whether monocular vision confers a risk to driver safety or affects driving performance. They found inconsistency in the definition of monocular vision and suggested that the visual requirements for commercial driving may not be entirely relevant for personal use driving, given the greater intensity of visual challenge associated with long hours of commercial driving. The review conducted for the U.S Department of Transportation (2005), of 1960 to 2000 literature regarding medical conditions and driving, found evidence from the 1960s-1980s that drivers with monocular vision had a greater number of crashes, more hazardous driving patterns, and a poorer driving performance compared with drivers with normal vision.

One primary study investigated whether unilateral vision impairment or amblyopia (lazy eye) are associated with the uptake of drivers' licences and crash risk among young adults (Baker et al, 2019). The authors used New Jersey Traffic Safety Outcomes data for 66,253 young adults (aged 17 to 28) to calculate driving licence acquisition and motor vehicle collision rates for young drivers with unilateral visual impairment; amblyopia; and normal vision. Young adults with unilateral visual impairment were found to be statistically significantly less likely to acquire a driving licence than young adults with normal vision. However, no increased risk of collision was found to be associated with unilateral visual impairment or amblyopia.

4.1.3 Visual field loss

The visual field is the portion of the subject's surroundings that can be seen at any one time. Visual field loss or visual field impairment refers to a loss of part of the usual field of vision. An adequate field of vision is required by the DVLA in the national vision standards for driving. However, this is not routinely tested before the driving test, unlike visual acuity which is tested via the number plate test.[n] Visual field loss can occur because of a number of visual impairments and other conditions including stroke, glaucoma, diabetic retinopathy and age-related macular degeneration. The following section discusses the prioritised literature which relates to the impact of visual field loss on driving in general. Where the prioritised literature addresses visual field loss which occurs due to a specific visual impairment, this is discussed in the relevant section for that specific visual impairment.

The prioritised reviews and primary studies found mixed evidence regarding the impact of loss of visual field on rates of motor vehicle collision and driver performance. There is some evidence that the type, location and extent of visual field loss may be important to driver safety and driving performance. Owsley and McGwin's (2010) review identified several studies which explored the relationship between visual field loss and motor vehicle collision rates which, when accounting for driving exposure, did not find a statistically significant association. The authors commented on the lack of agreement across the studies on the definition of 'visual field impairment' and noted that the studies, which show a statistically significant association between visual field impairment and collision rates, may use more stringent definitions of visual field impairment such as binocular field impairment[o] or extent of visual field impairment in the worse eye. Kotecha et al (2008) briefly reviewed the evidence regarding visual field and driving and concluded that there is some evidence of an association between visual field impairment and the risk of motor vehicle collision.

One primary study which was included explored the association between visual field impairment and involvement in motor vehicle collision among Japanese drivers aged 40 or over (Okamura et al, 2018). At routine licence renewal (required every three years in Japan), drivers completed a written questionnaire to assess self-reported motor vehicle collisions, perceptions of driving and medical conditions, and were assessed using ophthalmic measures of visual field impairment including Integrated Visual Field and Esterman Visual Field tests. The authors conducted multivariate logistic regression modelling and found that visual field impairment was not statistically significantly associated with either self-reported or police-reported at-fault motor vehicle collisions. However, a statistically significant association with self-reported motor vehicle collision was found for those drivers who reported having a relevant medical condition (hypertension, diabetes, cataract, glaucoma, diabetic retinopathy, macular degeneration, high myopia or other relevant condition); drivers who received more traffic citations from the police; drivers who drove more often at night; and drivers who reported driving outside the lane.

This lack of a statistically significant association between visual field and motor vehicle collision was also identified by Woolnough et al (2013) in their historical cohort analysis of driving related skills and crash rate among older drivers. Older drivers from Canada, Australia and New Zealand were recruited to complete a suite of measures known as the Assessment of Driving Related Skills (ADReS) which indirectly measures crash risk using tests of vision (Snellen visual acuity and visual field by confrontation), cognition

(Trail Making Test part B and clock drawing test) and motor/somatosensory skills (Rapid Pace Walk test, manual test of range of motion and manual test of motor strength). No statistically significant differences were found between those participants who had been involved in a motor vehicle collision in the two years prior and those who had not been involved in a crash, in any of the ADReS sub scores, including vision, cognitive and physical measures.

Huisingh et al (2017) used in-car video recording and vehicle sensors to predict rates of future crash or near-crash involvement among older drivers aged 70 or over in six US areas based on their rates of crash or near-crash involvement over a two-year period. Their primary research study found that peripheral vision impairment in either eye was associated with an increased rate of major crash involvement (adjusted rate ratio (RR)=1.53; 95% CI, 1.02–2.29), whereas peripheral vision impairment in both eyes was associated with an increased rate of crash involvement (adjusted[p] RR=1.74; 95% CI, 1.18–2.56), major crash involvement (adjusted RR=2.32; 95% CI, 1.40–3.83), and at-fault crash involvement (adjusted RR=1.73; 95% CI, 1.14–2.61).

An earlier study conducted by Huisingh et al (2015) examined the association between field impairment and motor vehicle collision involvement in the last 5 years in 2000 drivers aged 70 years or older in Alabama, USA. The authors used an innovative visual field test specifically designed to focus on the visual field area which drivers use when viewing through the windshield of a vehicle or when viewing the dashboard while driving. Overall, drivers with visual field impairment were found to have a 40% increased rate of at-fault motor vehicle collision compared with drivers without a visual field impairment.[q] Visual field impairment in the upper field of vision was not associated with an increased rate of at-fault motor vehicle collision. However, impairment along the horizontal meridian and lower field of vision were associated with a 31% and 40% increased rate of collision involvement, respectively. Impairment in the left side of the field of vision was associated with a 49% increased rate of collision involvement, while impairment in the right side of the field and the vertical meridian locations were unrelated to collision involvement. The authors acknowledged that their findings may be specific to countries such as the US where vehicles are driven on the right side of the road, and traffic and lane markings in the oncoming lane are on the left-hand side of the driver. They noted that it would be of interest to determine if impairment on the right side of the field results in increased rates of motor vehicle collision for drivers in countries where vehicles are driven on the left (e.g., UK, Republic of Ireland, Australia, India, and Japan).

Owsley and McGwin (2010) also explored the evidence around the effect of visual field loss on driver performance, highlighting several studies with results which consistently indicated that drivers with visual field defects have impaired driving performance. However, the authors argued that these findings, particularly those from studies employing closed road circuits and simulated visual field impairment, may not constitute valid and reliable measures of driving safety in the real world.

A more recent review of the literature on the impact of visual field loss on driving skills (Patterson et al, 2019) concluded that most reviewed studies found that visual field loss impacts driving performance and that the types and extent of visual field loss impacted driving difficulty in different ways. However, Patterson et al included in their review all studies concerning visual field loss, whether or not that visual field was a symptom of, or co-occurred with, a visual impairment such as glaucoma or age-related macular degeneration. Complete visual field loss was found to confer more difficulty than partial loss, central defects were found to confer more difficulty than peripheral vision loss and a lack of evidence was identified regarding the effect that altitudinal field defect[r] has on driving performance.

Wood and Black (2016) reviewed the evidence on the specific impact of homonymous hemianopic and quadrantanopic field loss[s] and found inconsistency between the results from on-road and simulator studies of driving performance. Results from both types of studies indicated that drivers with hemianopia have difficulties with steering and staying in lane. However, the findings from the simulator studies indicated that drivers with hemianopia demonstrate unsafe driving while findings from the on-road studies indicated that many drivers with hemianopia can drive safely. The authors suggested methodological and sample differences between the types of studies may have led to differences in the types of participants who were recruited to take part in the studies. On-road studies were likely to have recruited current drivers with hemianopia who may have developed compensatory mechanisms, while being a current driver was not a requirement for taking part in simulator studies and so participants may have had less experience of driving with hemianopia.

There is limited evidence as to the extent to which drivers with visual field impairment moderate their driving safety and performance through adaptation and compensatory strategies. Owsley and McGwin (2010) identified a small number of studies which suggest that drivers with visual field defects tended to adapt their driving behaviour by using more scanning behaviour. They found a lack of evidence regarding both the extent to which drivers adopted more scanning behaviour and the extent to which drivers with visual field impairment restrict their driving. In their review, Patterson et al (2019) found that driving safety among drivers with visual field loss can be improved by certain compensatory mechanisms, with the caveat that several of the studies from which these findings were drawn had very small sample sizes. These mechanisms tended to be specific to the type of visual field loss, with reduced overall driving speed aiding compensation in drivers with central field loss and increased scanning aiding compensation in drivers with peripheral field loss. For drivers with hemianopia, there is some evidence that compensatory mechanisms such as increased head and eye movements may improve hazard detection and overall driver safety, but that not all drivers with hemianopia are likely to be able to develop these strategies. These compensatory strategies take time to develop, particularly in drivers who experience sudden onset of visual field loss (Wood and Black, 2016; Patterson, 2019).

A primary study examined the prevalence of visual field loss among drivers referred to the Driver Licence Authority (DLA) for detailed medical review in Victoria, Australia and investigated factors associated with licence outcome in this group (Muir et al, 2016). Drivers can self-refer to the DLA if they experience specific medical conditions, and the police, medical practitioners and members of the public can also make referrals.

Drivers may then be referred to a Medial Review Panel. The DLA can then assign a licence outcome regarding restrictions on the driver's licence. In this study, licence outcomes were categorised as pass (with or without conditions on driving), fail (licence is suspended), or referred for further review.

The authors screened 10,000 driver records held by the DLA for the presence of six conditions that can result in visual field loss; glaucoma, age-related macular degeneration, diabetic retinopathy, hemianopia, quadrantanopia and retinitis pigmentosa. Of the 194 cases of visual field loss identified, 57% received a licence outcome of pass (conditional or unconditional) and, of these, the majority did not have any conditions on their licence. In around a fifth of cases, the licence was suspended. The remainder were either referred to a specialist for further review, voluntarily surrendered their licence, or no licence outcome was recorded. Using logistic regression, four variables were found to be independently associated with licence outcome: visual field condition, age group, crash involvement and referral to the Medical Advisors. The authors speculated that the proportion of drivers receiving pass or fail licence outcomes may differ by visual impairment. However, this speculation was based on an extremely small sample of drivers with visual impairments (retinitis pigmentosa, n=2; age-related macular degeneration, n=3).

4.1.4 Impaired contrast sensitivity

Contrast sensitivity impairment, that is impaired ability to distinguish between objects and their backgrounds, especially in situations of low light, such as fog, glare, or at night, has obvious implications for driving related tasks. Low contrast sensitivity can be a symptom of certain eye conditions or diseases such as cataract, glaucoma or diabetic retinopathy. The following section discusses the prioritised literature regarding contrast sensitivity in general. Where the prioritised literature addresses contrast sensitivity in conjunction with a specific visual impairment, this is discussed in the relevant section for that visual impairment below.

Owsley and McGwin (2010) identified numerous studies which indicated a statistically significant association between impaired contrast sensitivity and driver self-restriction and self-modification of driving behaviour. The authors suggested that the lack of a statistically significant association at the population level may be due to the removal of drivers with significantly impaired contrast sensitivity from the driving population. Kotecha et al (2008) briefly reviewed the literature regarding contrast sensitivity and found mixed evidence regarding the relationship with motor vehicle collision. However, the U.S Department of Transportation's (2005) review of the literature from 1960 to 2000 drew the conclusion that impairments in contrast sensitivity are associated with higher rates of motor vehicle collisions.

Huisingh et al's (2017)[t] US primary study which used rates of crash or near-crash involvement over a two-year period to predict rates of future crash or near-crash involvement among drivers aged 70 or over found that impaired contrast sensitivity was associated with a higher relative risk of crash involvement. Impaired contrast sensitivity in the worse eye was associated with higher rates of crash involvement (adjusted[u]

RR=1.38; 95% CI, 1.05–1.81), major crash involvement (adjusted RR=1.54; 95% CI, 1.07–2.23), and at-fault crash involvement (adjusted RR=1.44; 95% CI, 1.08–1.93). Impaired contrast sensitivity in the better eye was not associated with higher rates of crash involvement. Due to the possibility that the rate of crash involvement was impacted by whether drivers had impaired contrast sensitivity in one or both eyes, the authors conducted further analysis to compare the rates of crash, and near-crash involvement, among those with neither eye impaired, with those with one eye or both eyes impaired. Compared with participants with neither eye impaired, participants with one eye impaired were more likely to have a crash (adjusted RR=1.39; 95% CI, 1.03–1.88), major crash (adjusted RR=1.56; 95% CI, 1.04–2.34), and an at-fault crash (adjusted RR=1.44; 95% CI, 1.04–2.00). Participants who had impaired contrast sensitivity in both eyes had a similar relative risk to those with impairment in only one eye.

In their primary population-based study of older drivers aged 70 or over in Alabama, U.S., Green et al (2003) examined the association between visual and hearing impairment and motor vehicle collision involvement in older drivers. When contrast sensitivity was used as the measure of visual impairment, both those with contrast sensitivity impairment alone (rate ratio = 1.42, 95%; confidence intervals = 1.00–2.02), and those with contrast sensitivity and hearing impairment (rate ratio = 2.41, 95% confidence intervals = 1.62–3.57) had higher rates of motor vehicle collisions than drivers with no visual or hearing impairments.

One of the prioritised reviews examined predictors of driving fitness in studies of Parkinson's Disease and driving performance (Crizzle et al, 2012). Parkinson's Disease is a complex neurodegenerative disorder which can lead to motor, cognitive, and visual impairments and may impact on someone's ability to drive. While the aim of Crizzle et al's review was not specifically to identify visual predictors of fitness to drive in people with Parkinson's Disease, the authors found that it is likely that contrast sensitivity is predictive of driving performance in drivers with Parkinson's Disease. In comparison, visual acuity was not found to predict driving performance in drivers with Parkinson's Disease. Owsley and McGwin (2010) also identified a small number of studies which indicated that improved contrast sensitivity is associated with improved driving performance, particularly in relation to cataract surgery, but the evidence regarding this is limited.

4.1.5 Cataract

Cataract refers to clouding of the eye lens which reduces vision and symptoms can include blurry or double vision, difficulty seeing at night and with bright lights. This can affect eyesight in several ways which are relevant to driving safety and driver performance. Cataract can result in compromised visual acuity, contrast sensitivity and visual field sensitivity. Most cataract cases are among older adults. Cataract can be effectively treated through cataract surgery, which involves replacing the clouded lens with an artificial one. The literature regarding cataract and driving addresses both the impact of cataract and the impact of cataract surgery on rates of motor vehicle collision and driver safety.

There is general agreement across the prioritised literature that cataract is associated with a higher rate of motor vehicle collisions, but that cataract surgery is effective in at least partially reducing the risk of collision.

A systematic literature review conducted by Agramunt et al (2016) explored the published literature regarding cataract and cataract surgery and driving outcomes to identify gaps in the evidence base. Regarding the association between cataract and motor vehicle collision, the authors highlighted evidence from the Impact of Cataract on Mobility Project conducted in the United States which found that older drivers with cataract were almost 2.5 times as likely to have had an at-fault crash in the previous 5 years than those without cataract. This figure was also quoted in the U.S Department of Transportation's (2005) review of the literature from 1960 to 2000 and Wood and Black's review (2016).

Agramunt et al (2016) also presented evidence that cataract surgery reduced the risk of motor vehicle collision in drivers with cataract but found that variations in study design mean it is not possible to determine whether first-eye surgery alone reduces crash risk and whether second-eye surgery provides additional reduction in crash risk. Owsley and McGwin supported this finding in their 2010 review, citing their own earlier work that cataract surgery had reduced the risk of future involvement in a motor vehicle collision by 50%.[v] The Road Safety Observatory's review (2013) presents evidence that 25% of cataract patients who had ceased to drive before surgery resume driving following surgery.

A primary study by Meuleners et al (2012), cited by Agramunt et al (2016) and Wood and Black (2016), evaluated the effectiveness of first eye cataract surgery in a population of drivers aged 60 years and over in Western Australia. This retrospective cohort study compared records of police reported crashes from 1997 to 2006 before and after first eye cataract surgery. The authors found a statistically significant reduction of 12.7% in all crash frequency following first eye cataract surgery (adjusted[w] risk ratio = 0.873; 95% CI 0.763-0.992).

This finding is supported in part by a primary study published more recently than the included review articles. Schlenker et al (2018) conducted a population-based study of 559,546 cataract patients aged over 65 in Ontario, Canada to determine whether cataract surgery was associated with reduced motor vehicle collisions. Based on data gathered on collision involvement four years prior to first-eye cataract surgery and one year following first-eye cataract surgery, Schlenker et al found that cataract surgery was associated with a 9% reduction in serious traffic crashes, which translates to a decrease in the crash rate from 2.36 per 1000 patient-years before first-eye cataract surgery to 2.14 per 1000 patient-years after surgery. However, as 71% of the sample underwent second-eye cataract surgery less than one year after their first-eye cataract surgery, the relative contribution of first-eye surgery to the reduction in crash rate and any additional contribution from second-eye surgery could not be elucidated. The authors also identified a number of characteristics which conferred a higher risk of motor vehicle collision among drivers with cataract, including general comorbidity[x] and osteoarthritis.

In their review of ocular disease and driving, Wood and Black (2015) cite a meta-analysis which suggested that cataract surgery was associated with an 88% reduction in the risk of driving-related difficulties. However, Agramunt et al (2016) found that the impact of cataract and cataract surgery on driving performance is not well evidenced. The authors identified studies which addressed either self-reported driving difficulty or closed road driving performance.[y] In general, the studies included in the review found that cataract was associated with an increase in self-reported driving difficulty and that difficulties with driving decreased after cataract surgery. However, the authors highlighted methodological issues with a number of the studies including assessing driving difficulty with general questionnaires containing only two driving related items and a lack of clarity regarding whether participants had had surgery in the first, second, or both eyes. Therefore, differential impact of first and second eye cataract surgery on driving difficulty could not be elucidated.

A small number of studies measured closed road driving performance in participants wearing cataract-simulating goggles, with the general finding that the simulated effect of cataract was associated with poorer driving performance. One study was identified in Agramunt's review, and also cited by Owsley and McGwin's (2010) and Wood and Black (2016), which addressed the impact of cataract surgery on closed-road driving performance on older drivers with bilateral cataract and found that drivers with cataract had poorer overall driving performance, which improved following bilateral cataract surgery.

Contrast sensitivity impairment often co-occurs with cataract in older drivers. Owsley and McGwin (2010) cited findings from their own work that, for older drivers with cataract, contrast sensitivity was strongly associated with recent history of a motor vehicle collision. This association was found to be twice as strong when contrast sensitivity impairment occurred in both eyes compared with only one eye.

Agramunt et al (2016) identified a gap in the literature regarding the self-regulatory driving practices of drivers with cataract. The review identified only two studies which addressed this issue and found that drivers with cataract restrict their driving to avoid situations which may cause them difficulty. In their review, Wood and Black (2016) highlighted findings that cataract surgery was more effective at reducing crash risk in men than in women, and suggested that this may be due to the tendency for women to restrict their driving to a greater extent than men.

4.1.6 Glaucoma

Glaucoma is a condition in which the optic nerve connecting the eye to the brain becomes damaged, potentially resulting in peripheral visual field loss, blurred vision and difficulty seeing bright lights. Though research involving people with glaucoma is often used to examine the relationship between visual field loss and driving, Owsley and McGwin (2010) advised against this in their review, due to the range of ways in which glaucoma can manifest from very mild to very severe impairment of the visual field.

Blane's extensive review of the literature regarding glaucoma and driving (2016) found mixed evidence as to the association between glaucoma and risk of motor vehicle conditions, presenting studies which found a statistically significant association and others which did not. Blane suggested that this lack of consensus in the literature may be due, in part, to the differences in severity of glaucoma, reliance on self-reported information and failing to adjust for other factors such as comorbidities. These conclusions are supported by Wood and Black's review of ocular disease and driving (2016) which cited much of the same literature regarding glaucoma and rates of motor vehicle collisions. Wood and Black (2016) found that elevated risk of collision generally does not occur until glaucoma is relatively advanced and suggested that early detection is of importance in maintaining driving performance.

A study highlighted by Owsley and McGwin (2010) and Wood and Black (2016) found that glaucoma patients with visual field impairment in the worse eye had an elevated rate of motor vehicle collisions, although this association was not found to be statistically significant. However, the authors argued that it would be inappropriate to attribute any increased risk to driver safety among drivers with glaucoma solely due to visual field impairment, citing findings that drivers with glaucoma had higher rates of motor vehicle collisions even after controlling for visual field impairment. The U.S. Department of Transportation's (2005) review of the literature (1960 to 2000) found that the prevalence of visual field loss is higher among people with self-reported glaucoma than it is in the general population.

A population-based primary study by Kwon et al (2016), also cited by Wood and Black (2016), examined the association between glaucoma and at-fault motor vehicle collision involvement over the previous 5 years in a sample of 2000 licensed drivers aged 70 or over who reside in Alabama, U.S. The study found that drivers with glaucoma had a 1.65 times higher rate of motor vehicle collisions than those without glaucoma after adjusting for age, and cognitive function. Furthermore, the authors found that visual field impairment was independently associated with an increase in the rate of at-fault motor vehicle collision involvement, which visual acuity and contrast sensitivity were not. They found visual field impairment in different subregions of the visual field impairment impacted rates of collision involvement to different extents. Drivers with glaucoma with impairment in the left, upper, or lower visual field had increased motor vehicle collision rates, whereas no association was found in the right visual field and areas along the vertical or horizontal meridian. These findings imply that visual field loss may be an important mechanism which underlies increased crash risk in drivers with glaucoma.

McGwin et al (2015) conducted a primary retrospective cohort study to evaluate the association between binocular visual field defects in drivers with glaucoma and risk of motor vehicle collision involvement. The study used data from 1994 to 2000 obtained from 438 drivers with glaucoma, aged 55 years or over, who had attended any of three university-affiliated ophthalmology and optometry practices specialising in the diagnosis and treatment of glaucoma in Alabama, U.S. Data on at-fault collision involvement was obtained from the Alabama Department of Public Safety. The study used three types of visual field measurement: threshold (a measure of sensitivity to light in each area of the retina), total deviation (a deviation of the threshold value at each point from an age-matched normative database) and pattern deviation (a measure of irregularity in the field). Binocular visual field measures were created for each participant. Drivers with severely impaired pattern deviation measures were twice as likely to have an at-fault motor vehicle collision compared with those not severely impaired (rate ratio (RR)=2.13, 95% CI 1.21-3.75). Those with severely impaired threshold (RR=1.49, 95% CI 0.81-2.74) and total deviation (RR=1.50, 95% CI 0.82-2.74) also had an increased, but not statistically significant, rate of at-fault motor vehicle collisions.

Primary research by Tanabe et al (2011), cited in Blane's (2016) and Wood and Black's (2016) literature reviews, compared the prevalence of motor vehicle collisions in the previous 10 years in individuals with primary open-angle glaucoma with a control group of drivers with normal vision. A statistically significant association was only found between the occurrence of collisions and primary open-angle glaucoma in the group with severe primary open-angle glaucoma and significant visual field impairment, compared with the control group. No statistically significant association was found for the groups of drivers with mild or moderate primary open-angle glaucoma.

Both Blane (2016) and Wood and Black's (2016) reviews considered the literature regarding glaucoma and driving performance and found that several studies have examined the association between glaucoma and driving outcomes but have reported conflicting results. On balance, it seems that glaucoma does have a negative impact on driver performance, with both on-road and off-road studies showing that drivers with glaucoma showed poorer driver performance.

It is unclear from the prioritised literature whether, or how, drivers with glaucoma compensate for the effects of visual impairment while driving. One UK primary study (Crabb et al, 2010) explored the characteristics of eye movement patterns when viewing a traffic scene in a small sample of drivers with bilateral glaucoma (n=9) and age matched controls (n=10) using 26 different hazard perception test films and eye tracking software. Across all hazard perception test films, drivers with glaucoma exhibited different eye movement characteristics to controls making statistically significantly more saccades[z] (P,0.001; 95% confidence interval for mean increase: 9.2 to 22.4%); more fixations[aa] per second (P,0.001; F1,25 = 53.4; mean increase 16.9%; 95% CI: 11.7 to 22.1%); and more smooth pursuits[bb] per second (P,0.001; F1,25 = 85.3; mean increase 18.4%; 95% CI: 14.4 to 22.4%) than the control subjects. The authors speculate that drivers with glaucoma make more saccades to search the image as a means of compensating for their restricted field of view.

Blane (2016) explored the link between visual and cognitive decline and briefly described the limited evidence that suggests a link between glaucoma and Alzheimer's disease due to shared or similar visual and attentional symptoms. However, it concludes that a causal or interactive relationship has not been clearly established.

The literature reviewed by Blane (2016) suggested that older drivers with glaucoma are less confident in their driving ability and are likely to experience difficulties with driving, and particularly with driving at night. Drivers with glaucoma also frequently alter their driving habits or give up driving.

4.1.7 Macular degeneration

Macular degeneration refers to central vision loss and may result in dimming of colours, objects looking smaller than they are and hallucinations. The limited evidence in the prioritised studies regarding macular degeneration indicated that age-related macular degeneration (AMD) may have an impact on driving performance. However, the effect on collision rates is not clear and may be obscured by self-imposed restrictions on driving, particularly among those with advanced AMD. The U.S. Department of Transportation review (2005) of literature (1960-2000) identified only one study which examined the impact of macular degeneration on older drivers. This simulator and on-road driving study included a very small sample of older drivers with macular degeneration and an age-matched control group with normal vision. The study found that drivers with macular degeneration had a lower rate of crashes than normal drivers, but it did not adjust for driving exposure, so the reduction could be explained by drivers with the condition driving less. Drivers with macular degeneration were found to have impaired simulator and overall on-road performance, typified by delayed braking times at stop signs, slower speeds, greater lane boundary crossings and not maintaining proper lane position.

More recent literature regarding macular degeneration and driving, presented in Wood and Black’s review of ocular disease and driving (2016), may go some way in explaining this result. The authors presented findings from a study that found statistically significant lower rates of motor vehicle collision for drivers with intermediate AMD compared with a control group of drivers with normal vision, but not for drivers with early or advanced AMD. It was suggested that drivers with early AMD may not yet have experienced a substantial loss in visual function and do not restrict their driving and so show a similar rate of motor vehicle collisions to drivers with normal vision, while drivers with intermediate AMD were likely to restrict their driving to avoid challenging situations and therefore show a lower rate of motor vehicle collisions compared with the control group. Wood and Black (2016) proposed that the unexpected results for the advanced AMD group may be due to the low number of active drivers, as many people with advanced AMD give up driving altogether. Wood and Black (2016) also provided findings from simulator studies that older drivers with binocular central scotoma[cc] have statistically significantly poorer pedestrian hazard detection rates when compared with age-matched controls.

4.1.8 Diabetes and diabetic retinopathy

Diabetes is not predominantly a visual condition but there is a requirement for drivers in Britain to inform the DVLA if they have diabetes which is treated by insulin. Diabetes can impact vision and driving safety in several ways. Hypoglycaemia[dd] can affect attention, reaction times and hand-eye coordination, as well as visual information processing and visual perception, particularly in difficult driving conditions such as low light. Longer term medical complications of diabetes such as cardiovascular disease, diabetic neuropathy, and diabetic retinopathy may also have a negative impact on driver safety and performance (Goldenbeld and van Schagen, I., 2016). Diabetic retinopathy is a visual impairment which is caused by diabetes and leads to damage to the blood vessels at the back of the retina, resulting in patches of vision loss and a lack of sharpness across the visual field usually in both eyes. This creates complexity in assessing the impact of diabetes and diabetic retinopathy on driving safety as not all drivers with diabetes experience diabetic retinopathy and those with diabetic retinopathy may experience additional complications from diabetes which impair their ability to drive.

In their review, Wood and Black (2016) found limited evidence of increased rates of motor vehicle collisions either in drivers with diabetic retinopathy, or with diabetes in general. In their review of the effect of diabetes on road safety conducted for the European Road Safety Decision Support System, Goldenbeld and van Schagen, I. (2016) cited a meta-analysis which showed that drivers with diabetes had an increased, but not statistically significant, risk of crashes when compared with a control group.

The U.S. Department of Transportation's (2005) review of literature (1960-2000) found that most of the literature on diabetic retinopathy and driving is concerned with the effects of panretinal photocoagulation (PRP), a type of laser eye treatment, for proliferative diabetic retinopathy[ee] on visual fields. Several studies were highlighted which indicated that treatment of diabetic retinopathy with PRP can result in visual field loss which means that patients would no longer meet the DVLA vision standards for driving.[ff] However, they acknowledged that rates of failure of the vision standard for visual field are variable, and that this was likely to be due to variations in sample size and differences in the interpretations of minimum field requirements. The potential negative impact of laser photocoagulation on aspects of vision required for safe driving such as visual field, colour vision, contrast sensitivity, dark adaption and glare sensitivity is echoed by Wood and Black (2016).

Wood and Black (2016) suggested that, given the limited evidence in this field and the complexity conferred by the concomitance of diabetes and diabetic retinopathy, it would be of greater value to consider the impact on driving safety of the specific aspects of vision which are affected by diabetic retinopathy, such as visual fields, contrast sensitivity and visual acuity.

4.1.9 Retinitis pigmentosa

Retinitis pigmentosa is a rare, inherited visual field impairment in which the light sensitivity of the retina slowly deteriorates, eventually causing blindness. Symptoms include difficulty seeing at night and tunnel vision. There was very limited evidence regarding retinitis pigmentosa in the prioritised studies. The U.S Department of Transportation's (2005) review of the literature from 1960 to 2000 found limited evidence of an association between the extent of visual field loss in drivers with retinitis pigmentosa and motor vehicle collision rates.

4.2 The number of UK drivers with a visual impairment

Research question 2: summary of findings

There was no evidence found in the included studies regarding the number or proportion of UK drivers with visual impairments; the proportion of drivers with a visual impairment who meet national vision standards for driving or pass the 'number plate test'; or the proportion of drivers with a visual impairment who do not declare their condition to the DVLA.

Very limited evidence was found in the included studies regarding the number of drivers whose licences had been revoked by the DVLA due to the drivers' inability to meet the national vision standards for driving.

One of the primary research questions for this review was regarding the number of UK drivers who have a visual impairment, the proportion of these drivers with a VI who meet national vision standards for driving (in terms of both acuity and field of vision, or acuity only)[gg] or pass the 'number plate test' and the proportion of drivers with a visual impairment who do not declare their condition to the DVLA. In Britain, the national vision standards for driving are as follows:

- Drivers must be able to read (with glasses or contact lenses, if necessary) a car number plate, made after 1 September 2001, from 20 metres.
- Drivers must meet the minimum eyesight driving standard by having a visual acuity of at least 0.5 decimal (6/12) measured on the Snellen scale (with glasses or contact lenses, if necessary) using both eyes together or, if the driver has sight in one eye only, in that eye.
- Drivers must have an adequate field of vision.

The 'number plate test' is conducted prior to the UK practical driving test and is one of the three parts which constitute the national vision standards for driving. The 'number plate test' is used as a proxy for checking visual acuity but field of vision cannot be assessed by the number plate test. Drivers must also declare if they have any conditions that affect their eyes and specifically anything that affects their field of vision or acuity (that is not corrected by wearing glasses or lenses).

Three of the prioritised studies, all evidence reviews, provided data which was relevant to research question two. None of the three studies included evidence on the number of UK drivers with visual impairments. It is likely that relevant evidence about the number of UK drivers with visual impairments is not held in academic publications or grey literature but statistics regarding the proportion of UK drivers who declare a visual impairment may be held by the DVLA.

The Road Safety Observatory's synthesis report on eyesight and driving (2013) found no official UK estimates on the number, or proportion, of drivers on the road whose eyesight would meet, or fail to meet, the minimum national standards. Studies included in the Road Safety Observatory's report estimate that between 1% and 5% of drivers in the UK have a visual acuity below the minimum standard for driving. It should be noted that the studies in the report which estimated levels of visual acuity were conducted by insurance companies and eyecare companies and as such were deemed to be of low quality methodologically.

A literature review by Little (2018) focused on evidence about drivers who would meet the requirements for either one of two visual acuity tests: the number plate test and the Snellen scale. The review highlighted one study which identified that there was uncertainty around the tests for those with a visual acuity between 6/7.5 and 6/36. All participants took both the number plate test and the Snellen test. Seventeen percent of participants with visual acuity in this range failed either the number plate test or the Snellen scale test, meaning that they would not have met the national vision standards for driving. The evidence presented stated that around one in six people in the UK with what was described as 'borderline visual acuity' would have difficulty meeting the visual requirements on both the Snellen chart and the number plate test. These findings apply only to drivers in general, and not to drivers who also have visual impairments.

No evidence on the proportion of drivers with a visual impairment who would meet the national vision standards for driving in terms of both visual acuity and field of vision, or visual acuity only, was found in the included studies. No evidence was found as to the proportion of drivers who would not meet the national vision standards for driving but would pass the number plate test. The included studies also did not present any evidence as to the proportion of drivers with visual impairment who would pass the number plate test. Some evidence was found in the prioritised studies that drivers with visual impairments may pass the number plate test and meet the national vision standards for driving. This is explored more fully in Section 4.3 below.

The UK Road Safety Observatory's synthesis report (2013) included information gained by correspondence with the DVLA that 5,285 drivers had their licences revoked because they could not meet the national vision standards for driving in 2011, this was reported as an increase of 8% from 2010. However, it is not known whether these licences were revoked due to visual impairment or poor visual acuity. There was no evidence from the UK about the proportion of drivers with visual impairments who declare their condition to the DVLA in the included studies.

A summary of scientific evidence brought together by the Older Drivers Task Force (2016; Appendix 2) highlighted a study in Quebec that found major disparities in the information given by drivers, compared with the information given by their physicians, in the age-based medical review forms completed regularly by drivers over the age of 75. Where a medical condition affecting the driver's vision was detected, this was included in the medical review forms by 98.2% of physicians and only 2.95% of drivers. This study concluded that reliance on self-reporting of medical conditions by drivers does not result in robust data being collected.

4.3 Visual impairments and testing processes

> Research question 3: summary of key findings
>
> From the included literature, three conditions were identified for which there was some limited evidence of an association with risk of road traffic collision and which cannot be identified by UK testing processes such as the nationals vision standards for driving or the number plate test. These were impaired contrast sensitivity, visual field loss and age-related macular degeneration.

The final primary research question examined as part of this review relates to whether there are driver visual impairments which are positively associated with risk of road traffic collision that cannot be identified via UK testing processes such as the national vision standards for driving or the 'number plate test' (outlined in Section 4.2 above). It should be noted that visual impairments may affect individuals in different ways and that not every person with a specific visual impairment would necessarily pass or fail the national standards for driving. In addition, if someone has a visual impairment which co-occurs with reduced visual acuity, it is not possible to say which of these factors might lead to failing a number plate test.

A total of five studies provided evidence for research question three: three were evidence reviews and two were primary studies. The studies included in this section are those which made an explicit link between a visual impairment and a testing procedure which is not included in UK testing processes, or which noted that the visual impairment was not currently tested for in UK testing processes such as the national standards for driving or the 'number plate test'. These studies identified three conditions which were positively associated with an increased risk of road traffic collision yet were not identifiable by the GB national vision standards for driving. The conditions were: impaired contrast sensitivity, visual field loss and age-related macular degeneration (AMD).[hh] While Section 4.1 concludes that the evidence regarding the association between these visual impairments and road traffic collisions is mixed, there is some limited evidence that each of these visual impairments may be positively associated with an increased risk of road traffic collision, particularly in combination with other conditions.

Impaired contrast sensitivity was recognised as a factor in road traffic collisions in three of the prioritised studies; two evidence reviews and one primary study. As discussed in Section 4.1 above, the systematic literature review by Agramunt et al (2016) found that impaired contrast sensitivity was a significant predictor of road traffic collisions among older drivers with cataract, with the authors indicating that this is not currently used as a visual standard for testing. On the other hand, the review found visual acuity was not found to be associated with road traffic collisions among older drivers with cataract, despite visual acuity being used as a visual standard for driving. There was also evidence that impaired contrast sensitivity negatively affects driving performance. In a primary analysis of break reaction speeds using a driving simulator, Zhang et al (2007) found that older drivers with impaired contrast sensitivity exhibited statistically significantly slower reaction times.

The literature review by Kotecha et al (2008), found that for patients with cataract their contrast sensitivity can reduce significantly but they experience only a slight reduction in visual acuity. Despite potential for gains in road safety, the standards of vision for driving in the UK do not include a measurement for contrast sensitivity function. The recommended measurement of contrast sensitivity in the reviewed studies was to use a Pelli Robson contrast sensitivity chart.

The national vision standards for driving identify that drivers must have an ‘adequate field of vision’. This condition was identified in three of the prioritised studies as an impairment that national vision standards for driving and the number plate test are unable to detect. The literature review by Kotecha et al (2008) concluded that national vision standards for driving are not based in evidence, in general, and fail to account for adequate visual field specifically. The review found that current UK standards are useful for detecting ocular abnormalities but not for fully assessing the visual skills required for driving. The authors argue that the Esterman test of visual field, the test usually carried out at the request of the DVLA after a driver declares a condition related to their field of vision, fails to adequately control for the impact of lack of visual fixation during the test. Instead the study recommends an integrated visual field test of the PROGRESSOR software applied to monocular visual field data from the Humphrey Field Analyser. This latter test was also used as a measurement of the visual field in Zhang et al’s (2007) study which found that visual field loss measured in this way was associated with slower initial reaction times.

The difficulty of establishing a clearly defined upper limit of visual field loss severity was discussed in Bohensky et al (2008). This review of government documents outlining eyesight requirements for driving in Western countries[ii] concluded that current guidelines in these countries are not based on scientific evidence and found that this had an adverse effect on the ability of policy makers to establish an upper limit for visual field loss at which driving no longer becomes safe. One study in the review noted that even among drivers with the same visual field loss conditions, risk of collision depended on a variety of other factors including the type of visual field loss, comorbid conditions and adaptation strategies.

Section 4.1.7 above discussed the association between drivers with age-related macular degeneration (AMD) and an increased risk of collision. In a UK-based experiment, Rathore et al (2012) found that the national vision standards for driving do not adequately identify those drivers with AMD. Rathore et al compared the use of two different types of charts to test for visual acuity: the Snellen chart and the early treatment diabetic retinopathy study (ETDRS) chart[jj]. Participants underwent both types of acuity test in combination with the UK number plate test at 20 metres. In total 26 failed the number plate test and 24 passed. Among those who failed, visual acuity ranged from 6/36 to 6/6 on Snellen and from 49L to 79L on ETDRS chart, whilst among those who passed acuities ranged from 6/12 to 6/5 on Snellen and from 67L to 85L on ETDRS. This meant a considerable overlap between those who passed and those who failed, suggesting that vision chart tests cannot accurately predict AMD patients' ability to pass the number plate test.

4.4 Revising the UK eyesight rules and testing regime

Research question 4: summary of key findings

The limited evidence which was found regarding the GB national vision standards for driving implies that the current standards are insufficient in identifying those drivers with the greatest risk of road collision. There was some evidence that the ETDRS is a more reliable test of visual acuity than the Snellen test.

The included international literature suggested changes to the visual acuity test and the inclusion of additional tests for contrast sensitivity, visual field and useful field of view. However, there was no consensus on how to measure these. There was mixed evidence as to the efficacy of age-based screening, and the need to balance the potential improvements to driver safety with the potential negative impacts of loss of mobility was highlighted.

In addition to exploring the evidence base for the three primary research question, the study also aimed to answer three secondary research questions. The first secondary research question explores whether there is evidence to support revisions to the GB driving eyesight rules or other eyesight testing regimes for drivers, and if so what these suggested changes are.

A total of 21 studies were prioritised which discussed research question four, 11 of which were secondary reviews and 10 primary studies. As with the three primary research questions, limited evidence was found relating to the UK specifically. For most of the reviews it is unclear which country individual studies discussed originate from. Where possible, research from the UK is highlighted.

These 21 studies provided evidence that international visual driving standards are not adequate, suggested changes to the GB DVLA national vision standards for driving and, from an international perspective, recommended the inclusion of additional tests which are better able to predict risk of collision.

As outlined in Section 4.3 above, evidence was found to support the argument that GB visual standards for driving are ineffective at testing for some driver visual impairments which are associated with risk of collision.

The Road Safety Observatory synthesis report (2013) found considerable support for revising GB driving eyesight rules. For instance, the UK Optical Confederation, a coalition of bodies which represent members of the optical industry, has argued that the number plate test is an unreliable test of visual acuity and does not comply with the standards required by the EU Directive 2009 or with UK law. They also raise concerns about the potential for variability within the test depending on lighting conditions and the reliance on an examiner's estimate of 20 metres.

This synthesis also found wide variability among eye health professionals in what is considered to be the optimum visual acuity for safe driving. A UK study, included in the synthesis, which surveyed the opinion of 100 general practitioners, 100 optometrists and 100 ophthalmologists found that 54% of GPs said patients with a 6/12 visual acuity, the national vision standard for driving, should not drive. The level of acuity at which the eyecare specialists would advise against driving ranged from $6/9^{-2}$ to less than 6/18, well outside the range for the GB standard for visual acuity. The study concludes that Snellen charts are a poor predictor of an individual's ability to meet the visual standard for driving.

A number of other studies agree with this conclusion. The review by Owsley and McGwin (2010) questions whether visual acuity is the best measure for a visual standard for driving. They argue that visual acuity testing does not fully measure the necessary visual skills for the safe operation of a vehicle. The authors state that visual acuity testing was originally designed for the management of eye disease and not the practical task of driving. In a non-systematic literature review, Noyce et al (2017) echo this finding. Their review concludes that there is not enough evidence to prove a statistically significant relationship between visual acuity and unsafe driving or to support the use of visual acuity tests to identify high risk drivers. They state that letter acuity tests were designed for the clinical diagnosis of eye disease and not as an evaluation of visual performance in driving, and that driving safety can be endangered by other visual impairments despite a driver having good acuity. Noyce et al also argue that visual-sensory impairments and eye diseases alone cannot identify people at risk of crash involvement. Kotecha et al (2008) reach a similar conclusion - that simple cut offs based on visual acuity and visual field are not sufficient to predict driver safety. However, they add that there is currently no conclusive evidence to support the use of more modern and sophisticated tests of driving ability.

Rathore et al (2012) explore, and make recommendations about, the type and level of visual acuity best suited for measuring safe driving. The evidence from this study suggests that the modified ETDRS is the most effective measurement of visual acuity as the size of the overlap between those who passed and those who failed the standard number plate test was smaller using ETDRS than the Snellen test (see Section 4.3 above for further details of the Rathore et al study). They also recommended a score of at least 77L in the ETDRS test as a pragmatic cut off for presumptive ability to drive safely, based on their analysis of the chances of passing the number plate test based on descending levels of visual acuity. A score of at least 77L gives an 85% chance of predicting an individual's ability to pass the number plate test.

GB standards for driving are examined by Little's (2018) review. She concludes that UK eyesight requirements for driving make it difficult for drivers to seek advice about driving cessation, especially as ocular disease becomes more common in an ageing population. The author believes that although the 6/12 vision standard for driving is generally an appropriate figure, there are problems in applying this test consistently as drivers do not respond in the same way to testing. The author believes that there needs to be flexibility on the part of eyecare professionals in interpreting the results of these tests.

Crabb et al's (2010) UK primary study discussed the findings from glaucoma patients who undertook a Hazard Perception Test (HPT). They found that the useful field of view (UFOV) in glaucoma patients when conducting an HPT is different to the general population. Although there were no explicit suggestions of changes to the testing regime for drivers, the authors conclude this evidence could support the addition of a UFOV component to the GB national vision standards for driving.

Several studies gave specific recommendations for changes to the GB vision standards for driving. In the 2013 Road Safety Observatory synthesis, the Optical Confederation concluded that the number plate test should be replaced with a more rigorous assessment of visual acuity performed under controlled conditions. The synthesis also found a meta-analysis of eight studies reporting relationships between UFOV and driving performance, that expressed the view that a UFOV measure would make eyesight requirements for driving more effective.

In 2016, the Older Drivers Task Force (2016) conducted a review of the evidence available on supporting driving into older age. The task force recommended that the mandatory age for self-declaration (i.e. when drivers are required to renew their licence) should increase from age 70 to 75 (the rationale for this is outlined page 45) and that with this renewal DVLA should require evidence of a recent eyesight test, conducted by an optician. They argued that the DVLA, insurers and others should encourage vision checks every two years, particularly from the age of 60 onwards.

One international primary study mentioned the need to measure visual field. In a cross-sectional study which included a survey, Tanabe et al (2011) found that only patients with severe primary open angle glaucoma have an increased risk of collision. In Japan visual field tests are only required if visual acuity is less than 0.5, in which case the visual field must be 150 degrees or more in the better eye. This means that the current Japanese criteria may be insufficient to identify those at high risk. Although this is a Japanese example, GB vision standards for driving also do not require a compulsory visual field exam.

There were many studies that recommended additional tests for vision that would be a better predictor of crash risk based on international data. These are relevant for the UK, given the alignment of national vision standards for driving across much of the world. For instance, in their review, Owsley and McGwin (2010) found research which concluded that both static and dynamic visual acuity measurements are more effective than conventional static visual acuity measurements alone at predicting collision. The authors contend that a more holistic approach is needed to effectively vision screen drivers. They suggest this should include tests of contrast sensitivity, visual field, processing speed and divided attention tests.

Bohensky et al (2008)'s review found that the available evidence indicates that visual acuity and visual fields do not adequately explain unsafe driving performance. As such they found support for other functional tests in addition to the vision tests currently in use in many countries. These include recommending; the useful field of view test, integrated visual field testing, measures of contrast sensitivity and additional measures of glare sensitivity as visual requirements for driving. However, other studies within Bohensky et al's review suggested that individual driving performance varies to such an extent that it is not possible to assess them by uniform standards and instead drivers should be subject to individual on-road driving tests. Specifically relevant to the study of older drivers, Bohensky et al (2008) add that setting uniform standards based on visual tests is an issue for older drivers who are more likely to have comorbidities and are more sensitive to differences in individual driving talent.

Many of these suggestions are echoed in other reviews. In a comprehensive review, bringing together evidence from 1960 to 2000, on the impact of medical conditions on driving and its implications for testing, the U.S. Department of Transportation (2005) suggest the inclusion of tests of dynamic visual acuity. This recommendation is due in part to the fact that dynamic visual acuity involves the ability to detect an object when there is relative movement between object and the person observing it. Furthermore, dynamic visual acuity starts to decline at an earlier age and accelerates faster than static visual acuity. They also suggest that measures of contrast sensitivity be included in assessments of older drivers and tests for peripheral vision for new and existing drivers at licence renewal. In addition, the authors contend that decisions regarding fitness to drive for people with macular degeneration should be made on a case by case basis.

Macular degeneration is also mentioned in another study as a condition which needs extra consideration for licensure. In a systematic review comparing the visual requirements for holding driving licences across the world, Yan et al (2019) recommend that measurement for contrast sensitivity would be an important additional test for ensuring driver safety, particularly for those with cataract or macular degeneration who may have difficulty driving in low-lighting conditions. Yet this review also highlights the need for more individualised assessments for driving licensure, due to individuals' varying ability to adapt to visual impairments. In addition, the Noyce et al (2017) review recommends the use of neurophysiological tests as a requirement for licensing that would make driving safer. These would test attention, perceptual and visuospatial ability, speed and reaction time, memory, trail making, executive function, and UFOV.

Based on the results of their research, primary studies also make recommendations about the inclusion of additional tests which would aid driver safety. Green et al (2013) conclude that a combined screening approach involving both hearing and visual impairment would be a useful tool to identify older drivers at risk of collision. A different approach is taken by Muir et al (2016) in their secondary data analysis of medical review cases from the licensing authority in Victoria, Australia. They find that the involvement of an expert medical advisory service resulted in increased likelihood that drivers with visual field loss would be allowed to continue driving and therefore may be an effective screening tool. The authors stated that the reasons for this unexpected finding were not clear but speculated that cases with the most obvious visual field defect which would disqualify a person from driving would not be referred to the medical advisory service and, for those who were referred, a greater level of medical advice and intervention was available to inform the decision.

A different screening tool is assessed in Woolnough et al's (2013) historical cohort analysis. In this they assess whether scores in the Assessment of Driving Related Skills (ADReS) test – a series of tests which measure visual, cognitive and motor/somatosensory functions related to driving - are associated with incidences of collision in older drivers. They find that, contrary to their hypothesis, there was no statistically significant association between performance in the ADReS and history of collision in the previous two years. Despite this, the study supports the recommendation of the ADReS to assess capability of driving in older adults as a cost-effective and easy to administer system. A further screening tool, Age-Related Driving Disorders (ARDDs), was tested and recommended by Hill et al (2011). They found that ARDDs screening, which measures age-related visual, cognitive and strength impairments, correctly identified one in six adults as 'high-risk' for ARDDs concluding that screening is a useful and necessary tool in the context of an ageing population.

Many prioritised studies assessed and recommended age-related screening and testing. Many US states use some form of age-related screening, such as requiring people to renew their licence in person or more frequently after a certain age (Tefft 2014). Other countries have requirements to renew licences more frequently after a certain age often in combination with mandatory age-based self-declaration of medical conditions which may affect aptitude to drive. For instance, in the UK most drivers will not have to renew their licence until age 70, thereafter they must renew every three years.

The debate over age-based screening is centred around balancing safety with individual mobility. The concern is that age-based screening has adverse effects on vulnerable groups who lack alternative access to transport and would therefore lose their mobility and often independence. Another concern is that certain groups may continue to drive unlicensed until they experience a crash whilst others will stop driving prematurely. For instance, the Older Drivers Task Force Research Report (2016, Appendix 8) found that women in the UK voluntarily surrender their licences at a faster rate than men, with the rate exceeding 10% at age 75 for women and aged 80 for men, despite often being fit to drive. The report also found evidence that older women are more likely to suffer from long-term conditions that do not affect their ability to drive a car but do affect their physical mobility and make travel by alternative transport difficult.

In their secondary data analysis of UK road casualties, Hawley et al (2015) of the Royal College of Optometrists recommend that vision tests become more frequent as drivers age. Specifically, based on their findings that older drivers are more likely to be involved in a collision where a visual impairment is a contributory factor, they recommend all drivers over 40 should have a vision check every five years with this increasing to every two years for drivers over 60. They propose drivers over 70 should have mandatory vision tests on renewal of their licence. The Older Drivers Task Force (2016) strategic report recommends changes to the DVLA mandatory self-declaration. They argue that the automatic requirement for drivers to notify the DVLA at age 70 of any medical condition that may affect safe driving should be raised to 75. The medical condition notification requirement was introduced more than 50 years ago when life expectancy was lower. They found no convincing evidence that drivers in the 70-75 age group present a specific risk justifying this requirement but did find evidence that the risk rate to drivers per mile driven rises more steeply after age 75.

The Older Drivers Task Force Research Report (2016, Appendix 8) also drew on evidence from reviews of European licencing policy, concluding that there was no evidence that general age-based screening had safety benefits. Evidence from North America found positive effects for some single measures for the oldest age groups, particularly vision testing, in-person renewal and restricted driving. The U.S Department of Transportation (2005) support this, presenting some evidence that US state level mandatory vision testing for re-licensure may improve traffic safety and reduce the economic costs of fatal collisions. This appears to be a trend whereby age-based assessment is effective at reducing collisions in the USA but not elsewhere. For instance, Martensen's (2017) rapid review finds that Canadian states with stricter licensing requirements towards older drivers had higher rates of collision for older drivers, although this was not statistically significant, whereas in US states which required in-person licence renewal there was a lower rate of crash involvement among drivers over 85 compared with states that did not and instead had email or online renewal.

Examining the issue of licence renewal in greater depth is Tefft's (2014) secondary data analysis of driving licensing policies and population-based fatal crash involvement data from 46 US states between 1986-2011. The study found variations in driver licence renewal periods between states of one year to 12 years with the mean renewal period for drivers over 85 being 4.4 years.

Overall the study found that no policy analysed had a statistically significant impact on fatal crash involvement for drivers under 85, suggesting a potential threshold at which risk of collision increases. The study also found in-person licence renewal was effective and associated with a 28% decrease in fatal crash involvement of drivers over 85 (adjusted RR: 0.72, 95% CI: 0.55-0.94). However, changes in requirements for vision tests were not statistically significantly related to changes in fatal crash involvement. That said, in those states where in-person renewal was not required, implementing a vision test requirement was statistically significantly associated with a reduction in fatal collisions for drivers over 85 (RRR:0.64, 95% CI 0.49-0.85). Furthermore, the study found weak evidence to suggest that renewing licences more frequently could lead to fewer fatal collisions, although this was not statistically significant.

Braitman et al (2010) apply age-related driving screening to a specific context in their analysis of the effectiveness of a driver program in Iowa designed to improve driver safety. All drivers must renew their licence in person and drivers over 70 must renew every 2 years. Vision testing is mandatory and some individuals also have to take a road test. These road tests have three outcomes: drivers may pass and renew, can renew with restrictions (by geography or time of day) or fail and lose their licence. The study found clear differences between drivers of these three groups. Those who were required to take a road test were older, as were those who ended up with restricted licensing. Incidence of visual impairment increased across the three groups with those who passed and renewed having better eyesight than those who passed with restrictions and those who failed and lost their licence. Those who were given restrictions had the highest number of self-reported collisions, although this relationship was not statistically significant. The article suggests that Iowa's restricted licensing program is successful at predicting older adults at risk of collision, concluding that this is particularly true in higher risk settings. In addition, the study quotes a supporting study which found that the risk of at-fault crash was 87% lower among drivers with licence restrictions compared with drivers with no restrictions, supporting the effectiveness of this as a method of improving driver safety.

4.5 Non-visual conditions which moderate the relationship between visual impairment and risk of road collision or casualty

Research question 5: summary of key findings

There was very limited evidence found in the included studies regarding the relationship between visual impairment and non-visual conditions which may impact the risk of road collision or casualty. As many of the included studies focus on the impact of visual impairment, participants with potentially confounding non-visual conditions are screened out of the research. There was some evidence that older drivers with both visual acuity and hearing impairments have higher collision rates.

Research question 5 concerns the evidence regarding the relationship between visual impairment and other non-visual conditions, such as head and neck mobility or cognitive impairments, which may impact on the risk of road traffic collision or casualty. The studies were also reviewed for any evidence to support revised or amended eyesight requirements for drivers who have both visual impairments and non-visual conditions.

In many of the studies included in this review, the impact of the visual impairment was the focus of the study and participants with additional non-visual conditions, such as

Alzheimer's, were actively screened out of the research due to the confounding impact these conditions may have. Therefore, the information regarding non-visual conditions which moderate the relationship between visual impairment and the risk of road casualty identified in this review is limited. Three of the prioritised studies contained findings which were relevant to this research question: one was an evidence review and two were primary studies.

A primary study by Green et al (2013) provides the most directly relevant evidence to this research question. Using a retrospective cohort study of a population-based sample of 2000 drivers, aged 70 or over in North Central Alabama, the authors explored the association between visual and hearing impairment and motor vehicle collision in the previous five years. Estimates of dual visual and auditory impairment in older adults range from 9% to 17% in the United States.

The findings indicate that, after adjusting for age, race, sex, number of miles driven, number of medical conditions, general cognitive status, and visual processing speed, older drivers with both visual acuity and hearing impairment had higher motor vehicle collision rates than drivers with no visual or hearing impairments (rate ratio (RR) = 1.52, 95% confidence interval (CI) = 1.01–2.30). Similarly, those with contrast sensitivity and hearing impairment (RR = 2.41, 95% CI = 1.62–3.57) had higher motor vehicle collision rates than drivers with no visual or hearing impairments. Drivers with visual acuity impairment or hearing impairment alone did not have statistically significant higher motor vehicle collision rates compared with drivers with no impairments, although those with contrast sensitive impairment alone did have higher collision rates (RR = 1.42, 95% CI = 1.00-2.02). It should be noted that the extent and type of hearing or visual impairment were not addressed in this study, and that the research only tested for visual acuity and not for specific visual conditions. US state requirements for vision screening at age-based licence renewal may remove drivers with significant visual acuity impairment from the roads, and therefore from this cohort. The authors suggest that a combined approach to screening for hearing and visual impairments may be useful in identifying older drivers at higher risk of road collisions.

Sandrin and Strang's (2016) evidence on this question was very limited. They present evidence that a number of conditions which impact the cognitive aspects of vision, could be associated with increased crash risk, including Parkinson's disease, Alzheimer's disease and multiple sclerosis. In addition, the authors acknowledge that medical and functional comorbidities, in addition to visual impairments, become more common with increasing age and that these could act as confounding factors in the relationship between vision and road safety. However, Sandrin and Strang do not present any evidence which examines the moderating influence of these.

The Older Driver Task Force Research Report (2016, appendix 2) highlights findings from a study in Quebec that showed that the relative risk of crash increases as the number of medical conditions increases, and that the greatest influence on crash risk is the presence of multiple conditions. The presence of three medical conditions incurs a risk odds ratio of 1.48 (95% CI 1.44-1.53) and four or more medical conditions incurs a risk odds ratio of 1.55 (95% CI 1.49-1.60).[kk] However, the study does not specify if one of these conditions could be a visual impairment. Again, the authors acknowledge the increasing fragility and likelihood of multiple conditions with age, but do not provide evidence directly relating to the risk conferred by visual impairment in combination with other non-visual conditions.

While the primary study by Keay et al (2009) does not directly address the risk of road collision, it explores the visual and cognitive factors associated with stopping or restricting driving in older adults. It could be argued that if older drivers make the decision to stop or restrict their driving, this is relevant as it could result in a reduced risk of road collisions. The study presented findings from two waves of the Salisbury Eye Evaluation and Driving Study (SEEDS), a longitudinal study of vision, cognition, and driving behaviour of older drivers living in the greater Salisbury (US) metropolitan area. The authors found that symptoms of depression (odds ratio (OR),1.08; 95% CI, 1.009 –1.16 per point Geriatric Depression Scale) and reduced contrast sensitivity (OR, 1.15; 95% CI, 1.03–1.28) increased the likelihood of older people either stopping driving or putting restrictions on their driving. The presence of depressive symptoms partially mediated the impact of visual and cognitive functional status on the decision to stop or restrict driving.

4.6 Risks related to driver visual impairment and the ageing population

Research question 6: summary of key findings None of the included evidence directly addressed the risks related to driver visual impairment in an ageing population. Some evidence was found in the included studies that the prevalence of visual impairments, driving difficulty and casualty risk increase with age. In addition, the presence of multiple co-occurring health conditions and sensory impairment increases with age, which may impact the safety of older drivers.

Research question 6 concerns evidence that the risks related to driver visual impairment may increase with an ageing population, with sub-questions regarding changes to the prevalence of visual impairments, and visual impairments combined with other non-visual conditions, in both the UK general population and the UK population of drivers.

Nine of the prioritised studies contained findings which were relevant to this research question. Five of the studies were evidence reviews and four were primary studies. None of the included studies specifically examined risks related to driver visual impairment in an ageing population. However, the studies described below provide evidence regarding the prevalence of visual impairment and driving difficulty increasing with age and an age-related increase in the likelihood of casualty resulting from an accident.

The Road Safety Observatory's synthesis report on eyesight and driving (2013) found that older adult drivers were under-represented in road casualties but over-represented in deaths as a result of collision. The report presented evidence that, when considered as a ratio of the number of car drivers involved in accidents per million licence holders, drivers aged 17-19 and 20-29 had the highest number of collisions, while those aged 60-69 and 70 and over had the lowest number of collisions. In 2013, people aged 70 and over accounted for 12.0% of the UK population, 6.1% of all road casualties, but 19.1% of all road deaths. This may be reflective of the restrictions that older adults may place on their own driving, such as reducing night time driving, speeds or distances driven. The over-representation of older adults in collisions resulting in their death is described as a result of the increasing physiological fragility of people as they age.

However, in an analysis of UK road casualties and contributory factors conducted for the College of Optometrists (Hawley et al, 2015), older drivers aged 60 and over were found to be more likely to be involved in an injury-collision where visual impairment, or illness and disability were a contributory factor. Contributory factors are assigned for collisions where the police are in attendance, although police officers are not required to assign a contributory factor. The assignment of contributory factors is largely subjective, reflecting the opinion of the reporting police officer, and are not necessarily the result of extensive investigation. This means that the casualties for which contributory factors are assigned may not be representative of all collisions.

Overall, drivers over 60 were no more likely to be assigned a contributory factor by the police than drivers under 60 but were more likely to be assigned the specific contributory factors of 'failed to look properly', 'failed to judge another person's path or speed', 'uncorrected, defective eyesight', and 'illness or disability, mental or physical'.

A review of evidence regarding visual function and fitness to drive, by Kotecha et al (2008), highlighted findings that, over the age of 50, drivers experience reductions in visual acuity, contrast sensitivity, stereoacuity and visual field. In addition, the prevalence of certain visual impairments including cataract, age-related macular degeneration, glaucoma and diabetic retinopathy increases with age. This is supported by a primary study from Japan (Kaido et al, 2013), based on a small sample of drivers, which found that older drivers may experience decreased functional visual acuity and increased frequency of transient decreases in visual acuity while driving.

Primary research undertaken as part of the EUREYE project, a study of visual impairment and quality of life in the older European population (Seland et al, 2011), indicated that, while the prevalence of visual impairments was around 3% across the six European centres included in the study, prevalence rates rose steeply with age. The most common causes of visual impairment associated with age were age-related macular degeneration, accounting for almost 50% of visual impairment, and cataract, accounting for 22%. The EUREYE study also indicated that older adults with visual impairments are continuing to drive. Across the six centres, 58% of those with stage 4 (final stage) age-related maculopathy reported still being able to drive a car.

A primary study of older drivers in Iowa (Braitman et al, 2010) explored the practice of placing restrictions on people's licences when licences were renewed at the age of 70. The study indicated that drivers who received restrictions on their licence (such as avoiding driving when the use of headlights is required, not driving outside a specific geographic area and speed restrictions) were likely to be older than those who received no restrictions, although the age range for each group overlapped. Those drivers who received restrictions also had higher self-reported rates of visual impairment and were also more likely to be restricting their driving themselves.

Vision is not the only sense which declines in older age. Evidence reviews by both Boot et al (2013) and Noyce et al (2017) highlighted a number of sensory impairments which occur more commonly with increasing age and which may co-occur with visual impairment, including hearing and vibration detection impairment. Boot et al (2013) presented evidence that older drivers are more likely to experience chronic health conditions such as heart disease, cancer, diabetes and arthritis which may affect drivers' head and neck mobility. While not included in this review as a visual impairment, it is important to note that both Boot et al (2013) and Noyce et al (2017) highlighted the importance of cognitive aspects of vision which may impact on driving ability, including visual search efficiency, useful field of view and speed of visual processing. All of these functions decline in older adults and may be associated with increased risk of motor vehicle collision.

While cognitive aspects of visual processing were beyond the scope of this review, the conclusions drawn by Boot et al (2013) and Noyce et al (2017) are important in drawing attention to the complexity and interactivity of sensory and cognitive decline in older drivers and the potential cumulative impact of this on driving safety. Noyce et al (2017) reviewed a range of neurophysiological tests and found that these correlate with on-road driving and simulator performance. Boot et al (2013) reviewed a number of ways in which the safety of ageing drivers could be improved through environmental countermeasures and training for older drivers. Overall, these findings suggest that, while the risks related to driver visual impairment may increase with an ageing population, countermeasures, such as road design to increase driving safety and training for ageing road users, could be undertaken to somewhat reduce this risk.

5 Discussion and conclusions

This section synthesises the findings of this review, addressing the research questions set out at the beginning of this report, provides a discussion of the overall completeness and quality of the evidence, and then offers some conclusions.

5.1 Overall quality and completeness of the evidence

Due to the need for an efficient review process, only 41 studies were prioritised for inclusion in this review. Therefore, only a proportion of the studies meeting the inclusion criteria were synthesised. Thus, the review conclusions are based on a proportion of all includable studies and do not comprehensively summarise all relevant evidence.

Although the prioritisation process was intended to ensure that evidence for all research questions was synthesised by the RER, some research questions are far better evidenced than others. The search string used in this RER was designed to identify evidence which would be relevant to the primary research questions (research questions 1, 2 and 3). While any evidence which was relevant to the secondary research questions (4, 5 and 6) has been included in this review, it may be that additional evidence would be found for the secondary research questions through a targeted search. In addition, it is likely that relevant evidence about the number of UK drivers with visual impairments (research question 2), in particular, is not held in academic publications or grey literature. It is likely that statistics regarding the proportion of GB drivers who declare a visual impairment are, however, held by the DVLA.

The quality of the evidence reviews included in this review is variable. Only one was a systematic review, which aimed to comprehensively find and synthesise a body of evidence, other forms of evidence reviews were less rigorous and are not explicit about their search strategy, inclusion criteria or the quality of the evidence they review. Many of the included evidence reviews cover multiple countries. We also included primary studies from countries of interest, namely USA, Japan, Australia and Canada. While the availability of UK evidence was of interest in this RER, a UK setting was one of multiple prioritisation criteria, so we cannot conclude that all relevant UK evidence was prioritised.

Many of the reviews included in this RER note the lack of agreement within the evidence base regarding the impact of visual impairment on driving safety. There is variability across studies in the measurement of visual impairment, the level of sight loss which is classed as a visual impairment, the type and severity of crash and consideration of potentially confounding factors such as driving exposure, self-regulation and the impact of physical health conditions.

Several primary studies which were prioritised in this review are also included within the prioritised evidence reviews, and this is highlighted in the text where possible. Their inclusion and prominence in the synthesis does not indicate that greater weight should be given to the evidence drawn from the primary studies than that drawn from evidence reviews.

For a number of visual impairments which were of interest to the Department for Transport, we were unable to find any includable studies among the prioritised studies for synthesis: our review does not include studies on cerebral tumour, arteriovenous malformation or diplopia. Given the rapid nature of this evidence assessment and the need to focus on a limited sub-section of the included evidence base for synthesis, we cannot conclude that there is no relevant evidence for these categories.

Finally, driving is a highly complex task and the impact of visual impairment is difficult to isolate due to drivers' self-regulation and compensatory mechanisms. While some studies do control for confounding factors such as age, gender and driving exposure, it is impossible to control for the full range of possible factors which could affect the relationship between driving and visual impairment. Particularly for those visual impairments associated with ageing such as glaucoma, cataract and age-related macular degeneration, other age-related factors may have an impact on driving performance. These may include sensory impairments such as hearing loss, reduction in cognitive processing speed and cognitive impairment, co-occurring medical conditions, decreased physical mobility and increased frailty.

5.2 Discussion

5.2.1 Evidence of the relationship between driver visual impairment (VI) and risk of road traffic collision or casualty

Overall, the prioritised studies contained very little evidence regarding the relationship between driver visual impairment and risk of road traffic collision or casualty in the UK. International evidence from the prioritised studies relating to driver safety and driver performance found that some visual impairments may be associated with an increased rate of motor vehicle collisions, but this evidence is far from definitive.

In general, the prioritised studies did not support a statistically significant link between visual acuity and motor vehicle collisions. There was a lack of agreement across the prioritised studies regarding the impact of impaired contrast sensitivity or visual field, with some indication that the type and extent of visual field impairment may influence driver safety. There is general agreement across the prioritised literature that cataract is associated with a significantly higher rate of motor vehicle collisions but there was mixed evidence regarding the impact of glaucoma and macular degeneration on driver safety. Very limited evidence was found in the prioritised studies regarding the impact of monocular vision and unilateral visual impairment, diabetes and diabetic retinopathy and retinitis pigmentosa on rates of motor vehicle collision.

Again, very little UK evidence was found in the prioritised studies regarding the extent to which driving conditions, driver characteristics or behaviour moderate the risk of road traffic collision or casualty involving drivers with visual impairment. The prioritised international evidence indicates that drivers choose to restrict their own driving in response to visual impairment, particularly glaucoma, cataract and age-related macular degeneration. This can include avoiding driving at night or in busy areas, restricting speed and distance travelled in a single journey and, ultimately, stopping driving entirely. In addition, there was some evidence that drivers with visual impairment, particularly glaucoma and visual field loss, compensate to some extent for the effects of visual impairment by employing different patterns of eye movement and increased scanning behaviour. Finally, there was evidence that treatment for some visual impairments can reduce the risk of motor vehicle collisions. This is particularly the case for cataract surgery, which has been shown to reduce collision rates. However, the treatment of diabetic retinopathy with panretinal photocoagulation may have the opposite effect, as this treatment can result in defects in the visual field.

Due to the limited data from the UK that was found in the prioritised studies, it was not possible to draw comparisons between visual impairment and risk of motor vehicle collision in the UK and other countries.

5.2.2 Evidence on the number of UK drivers who have visual impairments

In the studies prioritised for this rapid evidence review, there was no evidence on the number, or the proportion, of UK drivers who have visual impairments. There was also no evidence on the proportion of drivers with a visual impairment who pass the number plate test but do not have an adequate field of vision, or who have declared a visual impairment to the DVLA. There was no evidence from the studies of estimations of these figures, but the data may be available from DVLA records.

5.2.3 Evidence of VIs associated with increased risk of road traffic collision that are not identified through national vision standards for driving

The studies prioritised in this rapid evidence review identified three conditions for which there was some limited evidence within the included literature of an association with increased risk of road traffic collision and which are not identifiable by GB vision standards for driving. These were impaired contrast sensitivity, visual field loss and age-related macular degeneration (AMD).[ll] It is important to note that these studies were not all written about the UK although they were discussing countries with similar vision standards for driving.

One review, that used evidence from multiple countries, concluded that the current GB vision standards for driving are useful for detecting abnormalities but do not adequately assess the skills required for driving. That being said, the evidence presented in this rapid evidence review highlights the difficultly in establishing uniform vision standards for driving, particularly among older people who, as shown in several studies, are more sensitive to differences in driving skill, adaption strategies and comorbidities.

5.2.4 Evidence to support revisions to the UK driving eyesight rules or eyesight testing regime for driver

The review found some evidence to support revisions to the GB national standards for driving. One of the included reviews found considerable support for revising GB national standards for driving, stating that the ‘number plate test’ should be replaced with a test of visual acuity performed under controlled conditions. The same review also found wide variability in views from eyecare professionals on what an optimum level of visual acuity for driving would be, with this ranging from $6/9^{-2}$ to less than 6/18, well outside the range for the current GB driving standard for visual acuity. Several studies concluded that the Snellen chart is a poor measure of visual acuity and should be replaced. A UK study of patients with AMD recommended the use of the modified ETDRS (Early Treatment Diabetic Retinopathy Study) as a better approximation of safe visual acuity for driving.

As was the case with other research questions, more evidence was found based on international data which can then be applied to the UK. Considerable evidence was found to support the addition of a useful field of view component to national vision standards for driving, both in UK and international studies. For instance, one UK synthesis recommended a UFOV component should be included in the GB national vision standards for driving. In addition, following on from the evidence found in research question three, evidence was found to support the addition of measures of contrast sensitivity as measured by a Pelli Robinson chart, as well as a measure of visual field, although there was no consensus on how this should be measured. Two reviews recommended a measure of visual acuity which captures both dynamic and static visual acuity.

Several primary studies assessed screening tools, including a combined screening approach for hearing and visual impairment and age-related screening, such as the Age-Related Driving Disorders (ARDDs), which measures age-related visual, cognitive and strength impairments. However, the evidence from outside the US indicated that age-based screening policies, such as having different types and rates of licence renewal after a certain age, have little effect on reducing risk of collision. They were therefore, on balance, not being recommended, especially because of the potential negative impact on older people losing their mobility. The exception to this appears to be in the USA where age-based screening policies have been found to be effective at improving road safety.

5.2.5 Evidence on the relationship between non-visual conditions, VI and risk of road traffic collision

There was little evidence on the range of non-visual conditions, such as head and neck mobility or cognitive impairment, that moderate the relationship between visual impairment and risk of road traffic collision or casualty. Many of the prioritised studies actively screened out participants with non-visual conditions, so that their findings on the impact of visual impairments were not compromised. There was some evidence presented that non-visual conditions could act as confounding factors in the relationship between vision and road safety.

A primary study conducted in the U.S. showed that older drivers with both visual acuity and hearing impairment, or both contrast sensitivity and hearing impairment, had higher motor vehicle collision rates, compared with drivers with no visual or hearing impairments. The authors suggest that a combined approach to screening for hearing and visual impairments may be useful in identifying older drivers at higher risk of road collisions. However, it should be noted that this evidence only relates to visual acuity, and not to visual impairments, and that the U.S. age-based licence renewal requirements may have removed drivers with significant visual acuity impairment from the studied cohort.

5.2.6 Evidence indicating that risk related to driver VI may increase with an ageing population

There was no evidence in the prioritised studies which specifically examined risks related to driver visual impairment increasing in an ageing population. There was evidence regarding the prevalence of visual impairment and driving difficulty increasing with age and an age-related increase in the likelihood of casualty resulting from an accident.

There was mixed evidence on the relationship with age and risk of road traffic collision. One review found evidence that older adults were less likely to be injured as a result of collision compared with younger adults. The review also found that older drivers were more likely to be involved in fatal accidents as a result of collision, which was described as being due to the increasing physiological fragility of people as they age.

There is evidence that the prevalence of certain non-visual conditions increases with age and may have an impact on driving performance or be associated with an increased risk of motor vehicle collision. One study showed a decline in older adults of cognitive aspects of vision, such as visual search efficiency, useful field of view and speed of visual processing, which may be associated with an increased risk of motor vehicle collision. A further study also indicated that older adults with visual impairments continue to drive. Though not directly stated by this study, this suggests that any increases in prevalence of motor vehicle collisions among older adults may be due to older adults driving with impaired vision.

However, there was contradictory evidence that indicated that drivers with specific visual impairments choose to restrict their own driving in response to their impairment, such as not driving at night or restricting their speed. A primary study of older drivers in the U.S. indicated that drivers who received restrictions on their licence (such as avoiding driving when the use of headlights is required, not driving outside a specific geographic area and speed restrictions) were likely to be older, had higher self-reported rates of visual impairment and were more likely to be restricting their driving themselves, than those with no licence restrictions.

5.3 Authors' conclusions

Overall, there was evidence, backed by both evidence reviews and primary research studies, of an association between cataract and a higher rate of motor vehicle collisions. For all other visual impairments discussed in the prioritised literature, there was either mixed or no evidence to support an association. There was mixed evidence on the relationship between contrast sensitivity, visual field, glaucoma, macular degeneration and the rate of motor vehicle collisions. No evidence regarding cerebral tumour, arteriovenous malformation or diplopia was found in the included studies.

There was no consistent evidence to support a relationship between visual acuity and risk of road traffic collision. But there was discussion on the relative validity of the tests for visual acuity, with several studies concluding that the Snellen chart is a poor measure of visual acuity and one study from the UK recommending the use of the ETDRS test as a better alternative.

The only evidence on driving conditions, such as low light, was in relation to drivers modifying their driving behaviour. International evidence was found that indicated that drivers with a visual impairment, in particular glaucoma, cataract and age-related macular degeneration, may choose to avoid driving at night in response to their visual condition. Other forms of driver behaviour used to moderate the risk of road traffic collisions were: restricting speed, avoiding driving in busy areas, restricting the distance they travel, and ultimately ceasing to drive. There was also some evidence that drivers compensate for their visual impairments, particularly for glaucoma and visual field loss, by employing different patterns of eye movement and increased scanning behaviour.

There were three visual impairments identified for which there was some limited evidence of an association with an increased risk of road traffic collision and which are not currently routinely tested for in the GB national vision standard for driving. These are impaired contrast sensitivity, visual field loss and age-related macular degeneration.[mm] Changes suggested, in a range of different studies, to the existing GB national vision standards for driving included: introducing a measure of contrast sensitivity, a measure of visual field, and expanding the test for visual acuity to include both dynamic and static visual acuity. Age-based screening for licence renewal was not widely recommended as there was no conclusive evidence that this reduced the risk of collision and would have the associated impact of reducing the mobility of older people.

In relation to the suggested changes to the UK testing regime for driving, there was also no consensus across the prioritised studies on what a 'safe' level for driving is for a range of visual impairments which may increase the likelihood of being involved in a collision. This is further complicated by the issues raised on the ability to establish uniform visual standards when the impact an impairment has on one individual may differ considerably to the impact it has on another individual. In addition, the existence of other conditions which may interact with the visual condition to increase risk, makes any assessment of 'safe' levels of visual impairment extremely difficult.

There was little evidence on an association between non-visual conditions, visual impairment and risk of collisions, one recommendation from the U.S. suggested joint hearing and visual tests should be carried out. There was limited evidence presented that non-visual conditions could act as confounding factors in the relationship between vision and road safety, and that having multiple medical conditions increases the risk of road collisions.

There was no evidence among the prioritised papers on the number or proportion of visual impairments among drivers in the UK, and there was mixed evidence on whether the risk of motor vehicle collision increases as drivers age.

One UK evidence synthesis recommended changing the automatic requirement for drivers to notify the DVLA from 70 years of age to 75 years of age, as there was no convincing evidence that drivers in the 70-75 age group present a specific risk, but it did find evidence that the risk rate to drivers per mile driven rises more steeply after age 75. A further evidence review concluded that no policy they analysed had been found to have a statistically significant impact on fatal crash involvement for drivers under 85, suggesting a higher potential threshold at which risk of collision increases.

However, there was evidence from both evidence reviews and primary studies that the prevalence of certain visual impairments does increase with age, and that these visual impairments, such as cataract, age-related macular degeneration, glaucoma and diabetic retinopathy, may impact on driving performance or be associated with an increased risk of motor vehicle collision. Overall, the findings suggest that, although the risks related to driver visual impairment may increase with an ageing population, this risk could be somewhat reduced by employing countermeasures, such as changes to road design to increase driving safety and training for ageing drivers.

These conclusions regarding an ageing population and driving safety are supported by a very recent review by Gandolfi (2020), commissioned by the RAC Foundation and published following the finalisation of the list of prioritised studies for this review. Gandolfi finds that older drivers would benefit from support to self-restrict their driving behaviour and that access to older driver education programmes would help older drivers to understand the challenges which they will face in driving and provide the tools for them to self-evaluate their driving performance. She also suggests that assistive vehicle technology has the potential to improve the safety of older drivers, and that older drivers are willing to engage with new technology.

The conclusions drawn are taken from the 41 prioritised studies, and any gaps in the evidence discussed in this report may not necessarily be true across the entirety of the literature. A further review of the prioritised studies or a more systemic search for evidence for the secondary research questions may uncover further relevant research studies which could help add to the evidence base on the extent to which driver visual impairments pose a risk to road safety in the UK.

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[a] "Motor vehicles" as set out in the Road Traffic Act 1988 and defined as "any mechanically propelled vehicle intended or adapted for use on roads".
[b] Figures for Scotland are based on a five year aggregation of licensing data to increase sample size.
[c] Driving licences issued in Northern Ireland are the responsibility of the Northern Ireland Driver and Vehicle Agency.
[d] Visual acuity refers to the clarity of eyesight, measured by ability to identify letters or numbers on a standardised eye chart from a specific viewing distance.
[e] Austria, Belgium, Czech Republic, France, Germany and Sweden also have no requirement for visual testing at licence renewal.
[f] Casualty: A person killed or injured in an accident. Casualties are sub-divided into killed, seriously injured and slightly injured: https://www.gov.uk/government/publications/road-accidents-and-safety-statistics-notes-and-definitions/reported-road-casualties-in-great-britain-notes-definitions-symbols-and-conventions
[g] Vision standards available here: https://www.gov.uk/driving-eyesight-rules
The 'number plate test' is part of the national vision standards for driving. All those who meet national vision standards for driving must also pass the number plate test. Please note that the vision standards for driving also refer to field of vision which cannot be assessed by the number plate test. Drivers must declare on application and at any time if they have an underlying eye condition and where this may impact their visual field formal vision testing will be undertaken.
[h] The search string was designed to include only those articles from 2000 onwards. However, articles from beyond the date criteria may be included in the search results due to errors in the databases.
[i] "Motor vehicles" as set out in the Road Traffic Act 1988 and defined as "any mechanically propelled vehicle intended or adapted for use on roads".
[j] A list of studies addressing this topic which emerged from the screening were compiled and provided to the DfT.
[k] Statistical meta-analysis is the combination of data from a number of studies which address the same research question and use a similar methodology in order to derive conclusions about that body of research and determine overall trends
[l] Dynamic visual acuity is the ability to discriminate an object when there is relative movement between the object and observer. Tests of dynamic visual acuity assess visual acuity during head movement relative to baseline static visual acuity.
[m] The membership of the control groups was not specified in the review.

[n] If a driver declares a medical condition that affects their visual field they will be formally tested to ensure they meet the required standard before being issued with a provisional licence. Drivers are also obliged by law to notify a condition that they develop that may affect visual field.
[o] Binocular visual field impairment refers to visual field impairment in both eyes.
[p] Rate ratios for motor vehicle collision in this study were adjusted for age group, sex, race, education, number of medical conditions, rapid walk status, cognitive impairment status, sensation-seeking score, and prior crash involvement.
[q] All rate ratios were adjusted for age, sex, race, visual acuity, contrast sensitivity, visual processing speed, mental status score, and number of medical conditions.
[r] Altitudinal field defect is a condition in which there is defect in the superior or inferior portion of the visual field with respect to a horizontal midline.
[s] In homonymous hemianopic and quadrantanopic field loss, field loss is present in one half (hemianopic) or quarter (quadrantanopic) of the visual field on the same side on the vertical midline in both eyes.
[t] Huisingh et al’s (2017) primary study used in-car video recording and vehicle sensors to assess rates of future crash or near-crash involvement among older drivers aged 70 or over in six US areas.
[u] Risk of motor vehicle collision was adjusted for age group, sex, race, education, number of medical conditions, rapid walk status, cognitive impairment status, sensation-seeking score, and prior crash involvement.
v Rate ratio for crash involvement = 0.47 (95% confidence interval, 0.23-0.94).
w Risk of motor collision was adjusted for individual gender, age, residential location, indigenous status, marital status, driving exposure and presence of comorbidities.
x Comorbidity refers to one or more diseases or conditions that occur along with another condition in the same person at the same time.
[y] In an assessment of closed road driving performance, a driver’s performance on a closed road circuit is tested against a number of set criteria, either by a driving evaluator or using vehicle-mounted cameras.
[z] A saccade is a quick, simultaneous movement of both eyes, classified by Crabb et al (2010) as an eye movement velocity faster than 30 degrees per second.
[aa] A fixation is the period of time where the eye is kept aligned with the target for a certain duration, classified by Crabb et al (2010) as an eye movement velocity of less than 1.5 degrees per second.
[bb] Smooth pursuits are eye movements which allow the eyes to closely follow a moving object, classified by Crabb et al (2010) as periods of trace where the eye movement speed was greater than 1.5 degrees per second but less than 30 degrees per second.
[cc] Scotomas can be caused by age-related macular degeneration. Scotoma is an area of partial alteration in the field of vision consisting of a partially diminished or entirely degenerated visual acuity that is surrounded by a field of normal, or relatively well-preserved, vision.
[dd] Hypoglycaemia is a condition in which the blood sugar level is lower than normal. It mainly affects people with diabetes.
[ee] There are two types of diabetic retinopathy: background and proliferative.
[ff] People with diabetic retinopathy must notify DVLA if they have it in both eyes and a visual field test will be conducted to check whether standards can be met.
[gg] Vision standards for driving available here: https://www.gov.uk/driving-eyesight-rules
The ‘number plate test’ is part of the national vision standards for driving so all those who meet national vision standards for driving must also pass the number plate test. Please note that the vision standards for driving also refer to field of vision which cannot be assessed in the number plate test.
[hh] Drivers in the UK must declare if they have any conditions that affect their eyes and specifically anything that affects their field of vision or acuity (that is not corrected by wearing glasses of lenses).

[ii] Australia, Canada, New Zealand, the United States, the United Kingdom, and the European Union.
[jj] The ETDRS charts are also known as LogMar charts.
[kk] The odds ratio for drivers with no medical conditions is 1.

[ll] Drivers in the UK must declare if they have any conditions that affect their eyes and specifically anything that affects their field of vision or acuity (that is not corrected by wearing glasses of lenses).
[mm] Drivers in the UK must declare if they have any conditions that affect their eyes and specifically anything that affects their field of vision or acuity (that is not corrected by wearing glasses of lenses).