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Associations between vision impairment and driving performance and the effectiveness of vision-related interventions: A systematic review

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ABSTRACT

Introduction: This systematic review aims to (1) investigate the associations between vision impairment and driving performance, and (2) evaluate the effectiveness of vision-related interventions to improve driving performance.
Method: Medline (Ovid), EMBASE and Global Health electronic databases were searched from their inception to March 2022 for observational and interventional English-language studies. The population of focus were licensed drivers of all ages of four-wheeled motorised vehicles. The primary outcome was measures of driving performance from naturalistic driving and/or on-road closed circuits. All screening, data extraction and critical appraisals were completed independently by two authors.
Results: 27 studies (n = 6358 participants) from the 4281 identified in the search were included in this review. All but one study, an RCT, were observational. Only 2 cross-sectional studies were rated as high risk of bias. The majority of papers (80 %) were limited to older drivers. There were 33 different performance measures reported. Poor driving performance was associated with glaucoma, AMD and monocularity, and measures of vision function including contrast sensitivity, visual acuity and visual fields. From the vision-related interventions identified only cataract surgery and toric refractive correction for astigmatism were shown to improve driving performance on selected measures.
Conclusion: Despite differences in outcome measures, there is consistent evidence for associations between vision impairments and poor driving performance. This review highlights the importance vision has on an individual's ability to safely drive and complete common manoeuvres. Early detection and management of eye conditions may help decrease the likelihood of crashing and road traffic injuries.

Introduction

Poor vision including impairments in visual acuity, contrast sensitivity and visual fields, caused by either age-related declines or specific eye diseases, have been shown to worsen different measures of driving performance. (Owsley and McGwin, 2010) These measures attempt to capture how a driver can safely operate a vehicle and include specific driving manoeuvres, such as lane changing and hazard avoidance, and

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can be combined into overall driving scores or error counts. (Owsley and McGwin, 2010) When drivers make performance errors, crash risk can increase by 18.2 times. (Dingus et al., 2016) These surrogate measures of driving safety can be investigated through on-road driving circuits with a trained driving instructor or more recently, "naturalistic" driving using in-vehicle monitoring systems which provide insight into everyday driving behaviour. The associations of deficits in vision with driving performance worldwide for drivers of all ages has not been systematically reviewed.

The United Nations' (UN) Sustainable Development Goals (SDGS) aim to halve road deaths by 2020 (Target 3.6) and provide safe and sustainable transport systems for vulnerable road users (Target 11.2). (UN. #Envision, 2015) A greater understanding of the associations between vision and driving performance across all ages can inform policy and direct investment in eye health services. As part of the *Lancet Global Health Commission* on Global Eye Health, this systematic review aimed to (1) investigate the associations between vision impairment and driving performance, and (2) evaluate the effectiveness of vision-related interventions to improve driving performance.

Material and methods

This systematic review is reported using the PRISMA guidelines (*Appendix A*) and its protocol has been published. (Nguyen et al., 2020) Briefly, an electronic database search on Medline (Ovid), EMBASE and Global Health was conducted from their inception to March 2022 with no geographic restrictions. The search terms included terms for motor vehicle crash involvement and driving cessation as a review on these outcomes measures was conducted in parallel to this review (*Appendix B*). Table 1 describes the inclusion and exclusion criteria for studies included in this review.

The population of focus was all four-wheeled licensed drivers of all ages. The outcome of interest was driving performance which included overall driving scores and errors, and other measures of driving performance such as lane keeping, braking, and speed control. These outcomes were assessed using on-road driving tests or "naturalistic" driving with in-vehicle monitoring. Studies which used driving simulators were omitted to restrict the scope of the study to direct measures of driving and associations with habitual vision. Further, studies investigating self-regulatory driving behaviours (e.g. night driving avoidance) were excluded.

All titles, abstracts, and full-texts were reviewed independently by two investigators using Covidence systematic review management software (Covidence non-profit SaaS Enterprise, Melbourne, Australia). All discrepancies were resolved via consultation with a third investigator. Similarly, data extraction was completed independently by two investigators using data extraction forms adapted from the Joanna Briggs Institute (JBI) templates for observational and systematic review study designs, and Cochrane templates for interventional studies. Data extracted from the studies included design, participant and setting characteristics, exposure type and definition, intervention details (if any), outcome measures, and relevant effect measures.

Overall risk of bias for all included studies was completed by two investigators independently with conflicts resolved by a third investigator. All quality assessments were conducted using the relevant JBI critical appraisal tools. (Adelaide Uo, xxxx) Each question on the relevant tools were categorised into either selection, detection, confounding, validity, performance, attrition, or allocation bias. Each study was given an overall "score" for bias depending on how each question was answered (Yes = 1, No = 0, Unsure or N/A = 0). The final scores were used to assign each study as low, medium, or high risk of bias, with lower scores indicating higher risk of bias.

Table 1
Study inclusion and exclusion criteria.

Inclusion	Exclusion
• Interventional (RCTs) and observational (cohort, cross-sectional, case-control and case series) studies. • Systematic reviews with *meta*-analyses • Studies on drivers of four-wheeled motorised vehicles of all ages. • Studies looking at the following exposures of interest: impairment in measures of vision (visual acuity (VA), contrast sensitivity (CS), visual field (VF), and glare sensitivity (GS)) or specific eye conditions including but not limited to glaucoma, cataracts, age-related macular degeneration (AMD), diabetic retinopathy (DR), stereopsis disorders and colour vision deficiencies. • Studies on interventions such as vision screening, refractive correction, cataract surgery, anti-VEGF injections and other treatments to improve vision.	• Literature reviews and narrative systematic reviews. • Commentary articles, dissertations, abstracts, editorials and conference presentations. • Studies using simulators or investigated either self-regulatory driving behaviours (e.g. night driving avoidance), or self-reported measures of driving safety. • Studies on populations with specific medical conditions (e.g. dementia, epilepsy, stroke and history of medical events such as syncope), low vision or vision difficulties caused by other medical conditions (e.g. hemianopia caused by brain damage).

Statistical analysis

Associations between vision impairment and vision-related interventions with driving performance were summarised with appropriate effect measures (relative risk (RR), hazard ratio (HR) and odds ratio (OR) for binary data, and standardised mean differences for continuous data. As there were many measures of driving performance, measures validated against crash risk were prioritised in synthesis of results. Reporting of the narrative summaries were guided by the SWiM guidelines. (Campbell et al).

Results

From the electronic database search, 5111 studies were identified after the removal of 4868 duplicates. After title and abstract screening, 242 studies remained for full-text review after which 217 studies were excluded leaving 26 studies. An additional study not picked up in the search was identified by authors, thus the final review includes 27 studies for data extraction (n = 6358 participants) (Fig. 1). There were 19 studies which reported on multiple measures of driving performance together and eight studies that only looked at one. There were 14 cross-sectional studies, 8 case-control studies, 4 cohort studies, and 1 randomised control trial (RCT). All but four studies had sample sizes<200 participants and only three studies had participants of mean age<50 years. All studies were from high-income countries (HICs). Risk of bias for each study is shown in *(Appendix C)*. Overall, only two studies, both cross-sectional, were rated as high risk of bias, with the remaining rated as either medium or low risk of bias.

Across the 27 studies there were 87 combinations of independent variables (measures of vision impairment or vision related interventions) and outcome measures (Fig. 2) and most results were for single studies. All measures of vision impairment had measurable impact on at least one measure of driving performance.

Overall driving Errors, scores and counts

Overall driving scores were lower for drivers with glaucoma, (Bhorade et al., 2016; Haymes et al., 2008; Lee et al., 2018; Wood et al., 2016) age-related macular degeneration (AMD) (Szlyk et al., 1960). 1995,; Wood et al., 2018) and self-reported eye disease, (Wood, 2002) with greater impact with severe disease. All four studies on glaucoma (n = 267 participants) found drivers with glaucoma made more than double the rate of critical errors needing driving instructor intervention than drivers without glaucoma, (Wood et al., 2016) had lower mean driving performance scores, (Lee et al., 2018) and were four times more

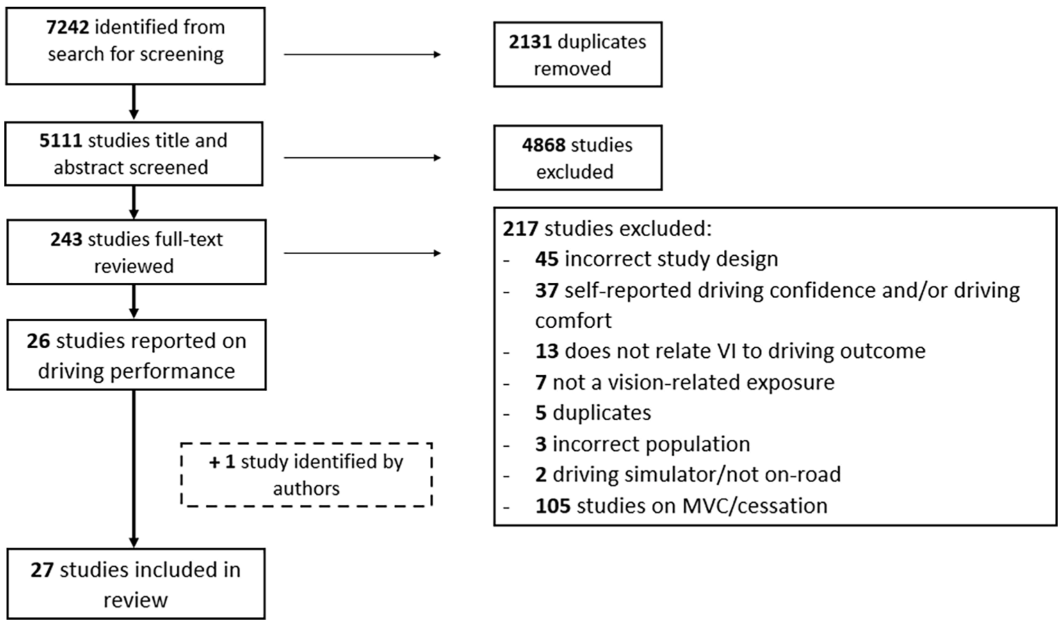

Fig. 1. Flow chart of search with papers reporting on driving performance.

likely to receive a marginal/fail score for the driving assessment. (Bhorade et al., 2016) Only one study found no difference between the median driving score of drivers with glaucoma and drivers without. (Haymes et al., 2008).

Two studies ($n = 104$) compared drivers with and without AMD, and one study found drivers with AMD to have a three times greater rate of making driving errors; with this rate increasing to four and ten times in drivers with intermediate and severe AMD, respectively. (Wood et al., 2018) The proportion of terminated driving assessments due to safety concerns was also three times higher in drivers with AMD compared to drivers without AMD. However, a 1995 study found no significant differences between the overall road test score for drivers with and without AMD ($p \leq 0.07$). (Szlyk et al., 1960). 1995).

A final study comparing the on-road driving performance of older drivers with either mild or moderate/severe self-reported ocular disease ($n = 46$) to drivers without vision impairment across all age groups ($n = 93$), found drivers with self-reported ocular disease made significantly more errors ($p < 0.001$). (Wood, 2002).

All four studies ($n = 375$) evaluating visual acuity found associations with overall driving performance scores and number of errors made whilst driving on an on-road circuit. (Szlyk et al., 1960). 1995,; Dawson et al., 2010; Kimlin et al., 2020; Wood and Mallon, 2001) Better visual acuity was positively correlated with better scores in driving performance, with decreases in visual acuity additionally linked to poorer night-driving performance. (Szlyk et al., 1960). 1995) One study found older drivers with greater near visual acuity loss made more driving errors during the day, however another study reported impairments in distance visual acuity when driving at night to be responsible for greater safety errors. (Dawson et al., 2010; Kimlin et al., 2020) Older drivers with vision impairment were also found to make more errors, judged by both a driving instructor and an occupational therapist, than the younger, middle-aged and older drivers without vision impairment. (Wood and Mallon, 2001).

Six studies ($n = 543$), all using on-road driving circuits, looked at the effect of contrast sensitivityloss on overall driving performance scores and errors committed. (Haymes et al., 2008; Lee et al., 2018; Szlyk et al., 1960). 1995,; Wood, 2002; Dawson et al., 2010; Carr et al., 2016) All but two studies found poor contrast sensitivity to significantly predict worse driving scores. (Dawson et al., 2010; Carr et al., 2016).

The results concerning visual field impairments and overall driving performance assessed using on-road driving routes were mixed (three studies, $n = 163$). (Haymes et al., 2008; Lee et al., 2018; Coeckelbergh et al., 2004) Two studies involved drivers with glaucoma but only one found poor driving scores to be associated with visual field defects. (Haymes et al., 2008; Lee et al., 2018) The third study which included drivers with either AMD, glaucoma or retinitis pigmentosa, found overall visual field defects to not be correlated with overall driving scores (Spearman's $p = -0.150$), however drivers with either peripheral or central field defect were more likely to fail the driving test compared to those with only mild field defect ($p < 0.05$). Further, more participants with peripheral visual field defects, attributed to a diagnoses of glaucoma, failed the driving test compared to drivers with central field defects all diagnosed with AMD. (Coeckelbergh et al., 2004).

The only study ($n = 162$) looking at vision screening for visual acuity and contrast sensitivity as a tool to predict driving performance found no correlation between failing screening and driving ability. (Spreng et al., 2018).

Another looked at the overall night-time driving score of participants wearing different contact lenses (spherical or toric) on an on-road circuit. (Black et al., 2019) All participants ($n = 10$) in this RCT were diagnosed with low to moderate bilateral astigmatism. After adjusting for lap time and run order, correction of astigmatism using toric lenses resulted in significantly better overall driving scores ($p = 0.003$) than spherical lenses.

Driving performance measures

Glaucoma was found to worsen driving performance on all eight manoeuvres related to safe driving: speed, braking, lane-changing and lane-position control, gap selection and judgement, blind spot checking, vehicle manoeuvring/control, hazard recognition and avoidance and sign recognition (Fig. 2). Drivers with bilateral moderate and or advanced glaucoma were found to be twice as likely to require more than one brake intervention on an on-road driving test from an instructor compared to drivers without glaucoma. (Bhorade et al., 2016) The number of braking errors, however, were not significantly different between drivers with glaucoma with mild to moderate visual field loss and the control group of drivers without glaucoma ($p = 0.28$). (Wood et al., 2016) Drivers with glaucoma were found to have poorer lane control than drivers without glaucoma in two thirds of studies, (Lee

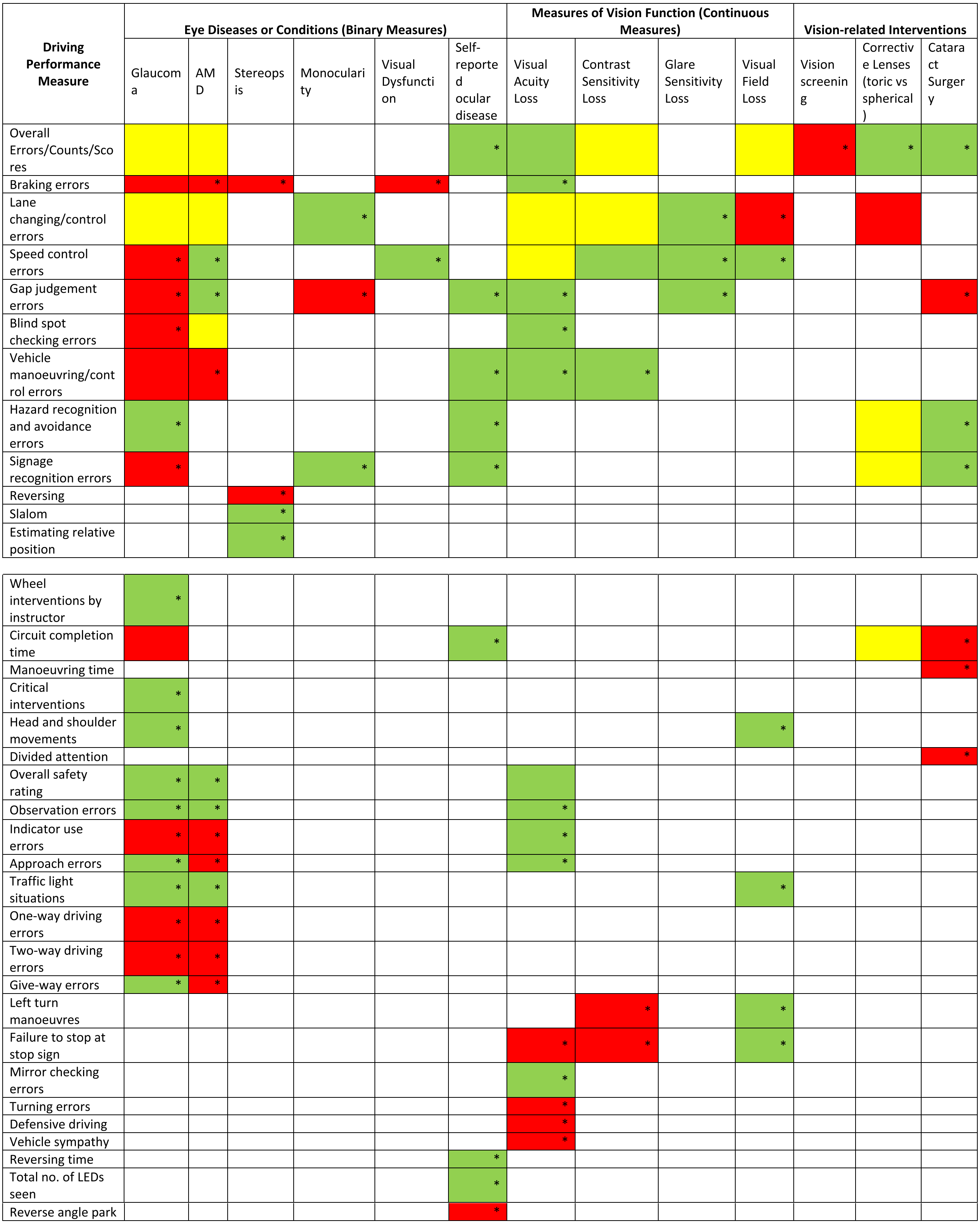

Fig. 2. Matrix illustrating the relationship between vision impairment and vision-related interventions on driving performance measures. Red = vision condition is not associated with driving error and or driving performance measure; Yellow = vision condition is not consistently associated with driving error and or driving performance measure; Green = vision condition is associated with driving error and or driving performance measure* outcome only reported by one paper. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

et al., 2018; Wood et al., 2016) specifically those with binocular field loss ($p \leq 0.05$). (Kasneci et al., 2014) Even though there were no differences in performance when time spent unsafely lane-crossing was used as a measure of poor lane control ($p = 0.16$), (Lee et al., 2018) drivers with glaucoma were found to make significantly more lane position errors ($p = 0.01$) when assessed using on-road circuits than drivers without glaucoma. (Wood et al., 2016) Drivers with glaucoma also hit significantly more hazards on an on-road driving circuit compared to drivers without glaucoma ($p = 0.04$). (Lee et al., 2018) Further, gap judgement performance was worse in drivers with glaucoma and worse binocular VF than those with sufficient field of vision. (Kasneci et al., 2014) Errors in speed control, blind spot checking, vehicle manoeuvring and signage recognition were not affected by the presence of glaucoma in these three studies.

Drivers with AMD (two studies; n = 104) were found to make significantly more errors in lane positioning, observance, and merging manoeuvres than control drivers without AMD. (Szlyk et al., 1960). 1995,; Wood et al., 2018) They were also found to have more points deducted for driving too slow (defined as 5mph below the speed limit) on an on-road driving circuit than drivers without AMD ($p \leq 0.02$). (Szlyk et al., 1960). 1995) Significantly more errors in gap selection were made by drivers with AMD compared to those without ($p = 0.036$). (Wood et al., 2018) Only one 1995 study found drivers with AMD (n = 21) made significantly more errors when checking blind spots ($p \leq 0.02$). Further, the same study found both better visual acuity and binocular contrast sensitivity in both AMD and non-AMD drivers to be significantly associated with better speed control ($p < 0.05$). (Szlyk et al., 1960). 1995) AMD presence did not affect braking control or vehicle manoeuvring errors (Fig. 2). (Wood et al., 2018).

Monocularity was investigated by one study (Fig. 2) comparing the driving performance of 40 monocular to 40 binocular truck drivers. (McKnight et al., 1991) Only signage recognition was found to be impacted, with recognition distances in monocular drivers significantly shorter in both day and night conditions ($p < 0.05$). Monocularity did not worsen lane keeping and gap selection and judgement performances.

The impact of self-reported vision loss, referred to in Fig. 2 as either visual dysfunction or self-reported ocular disease, on driving performance was investigated in two studies (n = 216). (Wood, 2002; Merickel et al., 2019) One study found drivers aged 65 years and older with poorer self-reported vision loss to have more erratic braking behaviours, errors in braking control and worse vehicle control whilst accelerating compared to drivers with milder self-reported vision loss; specifically on high-speed interstate highways at night ($p < 0.0001$). (Merickel et al., 2019) The other study found drivers with self-reported vision loss, when compared to drivers without vision loss, made more gap judgement errors ($p = 0.001$), took significantly longer to complete driving manoeuvres ($p = 0.001$), hit more on-road driving cones ($p = 0.025$), were worse at recognising on-road hazards ($p = 0.001$) and signs ($p < 0.001$), and hit more hazards ($p < 0.001$). (Wood, 2002).

Stereopsis impairment was found to only impact how fast a driver can move the vehicle in and out of cones (slalom) and relative position estimation performances. (Bauer et al., 2001).

Studies on the impact of specific measures of vision on driving performance reported mixed results (Fig. 2). A cross-sectional study found drivers with poor visual acuity to make more braking ($p = 0.03$), gap selection ($p = 0.02$), blind-spot checking ($p = 0.001$), and vehicle manoeuvring ($p = 0.004$) errors than drivers with normal vision. (Wood and Mallon, 2001) A prospective study found a strong correlation between total satisfactory driving manoeuvre and skills execution with contrast sensitivity in the better eye ($r = 0.6$; $p = 0.005$). (Haymes et al., 2008) The impact of measure of vision on lane changing abilities (two studies) was mixed. Even though one study reported visual acuity, contrast sensitivity and bilateral visual field loss to not be predictors of lane changing errors in drivers aged above 65 years, (Munro et al., 2010) the other found better VA ($p \leq 0.01$), CS ($p \leq 0.01$) and glare sensitivity ($p \leq 0.05$) to be strongly correlated with better scores in lane position and observance when merging or turning left or right. (Szlyk et al., 1960). 1995) Worse speed control and increasing errors in speed of approach have been linked to worse glare sensitivity ($p < 0.05$) (Szlyk et al., 1960). 1995) and CS ($p < 0.01$), (Baldock et al., 2008) respectively. Another study investigating contrast sensitivity, visual field and visual acuity through naturalistic driving with in-vehicle monitoring, found both contrast sensitivity and visual field loss to predict higher rates of deceleration events but only on low mileage drivers. (Keay et al., 2013).

Vision-related interventions and their impact on specific driving performance measures were investigated by four studies (Fig. 2). The only study (n = 162) looking at vision screening used the traditional measure of visual acuity with the addition of contrast sensitivity, as a tool to predict driving performance. The drivers in this study were 70 years and older and 21 % had moderate to severe deficits in contrast sensitivity. The combination of visual acuity and contrast sensitivity was not predictive of daytime driving ability. (Spreng et al., 2018) Two studies looked at the use of corrective lenses. One study was an RCT on drivers with uncorrected astigmatism given either toric or spherical lenses. (Black et al., 2019) This study found toric lenses to be better at reducing the number of hazards hit ($p = 0.022$) and increasing the number of signs recognised ($p = 0.021$) than spherical lenses. The difference in lane-keeping time between the two types of lenses, however, was not significant. The other study on corrective lenses looked at drivers with presbyopia corrected by either single-vision lenses, progressive-addition spectacle lenses, monovision contact lenses, and multifocal contact lenses. (Chu et al., 2010) Overall, there were no significant differences in either the number of road hazards hit, the number of signs recognised, or the lane-crossing times between the types of lens worn. The remaining study investigated whether cataract surgery could improve on-road driving performance and found post-op driving scores to improve for overall driving score ($p = 0.001$), road sign recognition ($p < 0.001$), road hazard recognition ($p = 0.001$) and avoidance ($p < 0.001$). (Wood and Carberry, 2006).

Raw data summary of all driving performance measures can be found in *Appendix D*. (Haymes et al., 2008; Lee et al., 2018; Wood et al., 2016; Szlyk et al., 1960). 1995,; Wood et al., 2018; Wood, 2002; Wood and Mallon, 2001; Coeckelbergh et al., 2004; Spreng et al., 2018; Black et al., 2019; Kasneci et al., 2014; McKnight et al., 1991; Merickel et al., 2019; Bauer et al., 2001; Baldock et al., 2008; Keay et al., 2013; Chu et al., 2010; Wood and Carberry, 2006; Keay et al., 2009; Eramudugolla et al., 2022; Swain et al., 20212021; Wang et al., 2021).

Discussion

This paper synthesises global data on the associations of vision impairment and vision-related interventions on driving performance. Both glaucoma and AMD, alongside declines in measures of vision function, were found to be associated with poor driving performance. These results support the findings of a complementary systematic review (Nguyen et al., 2020) which also found these vision impairments to be associated with either crash involvement and or driving cessation. Early detection and management of eye conditions is therefore an important strategy to promote road safety. As disease severity worsens, driving performance and timely treatment is critical. Licensing and healthcare systems are needed to ensure drivers have access to eye-care services including diagnosis and management of ocular disease, particularly older drivers where eye diseases are more common. Though there was limited evidence from interventional studies, corrective lenses are a relatively simple intervention to maintain and optimise vision for driving.

Despite vision being commonly assessed during licensure, only one study identified in this review examined vision screening and its association with driving performance. Despite no predictive value found in this study, other studies focusing on sole measures of vision function still consistently found poor visual acuity and contrast sensitivity to negatively impact driving performance, thus supporting the rationale for vision screening. A recent big data study found the likelihood of failing the visual acuity standards for driving to increase with age, particularly for those aged over 80 years whose fail rates increase every 2 years after 80. (Moore et al., 2022) Vision screening policies may have an impact in low- and middle-income countries (LMICs) where many drivers are licensed with vision loss that is treatable, such as refractive errors. (Dotse et al., 2019) It is estimated that more than 90 % of all persons with uncorrected refractive error are from LMICs and rural areas who, due to economic, social and health service barriers, are unable to access adequate eye- care services. (Ehrlich et al., 2019; Naidoo and Jaggernath, 2012) This is of concern as corrective lenses, as illustrated in this review, do help improve select driving performance measures. As LMICs also suffer from the highest crash involvement and road traffic injury rates, strategies are needed to improve accessibility of eye health services in order to complement vision screening for licensure and keep all road users safe.

Vision screening as a fitness-to-drive tool, however, should not be considered alone, with previous studies finding screening not accurate at predicting on-road driving performance. (Higgins and Wood, 2005; Silveira et al., 2007) Instead, combining vision assessments alongside psychometric tests may be better at evaluating on-road driving skills. (Grundler et al., 2020; Wood et al., 2013) For example, the "multi-D test", a computer-based test on colour reaction, vision motion sensitivity, and balance and postural sway, has high specificity and sensitivity for people with a vision impairment. (Anstey et al., 2020)" Further, higher scores in useful field of view assessments, and poorer scores in hazard perception tests and multi-D battery tests have all been shown to be good at predicting the risk of failing on-road driving assessments. (Anstey et al., 2020; Jones Ross et al., 2014; Myers et al., 2000) Inclusion of many of these additional assessments during license renewal, however, is not feasible. Future policies surrounding licensing and fitness-to-drive may instead aim to include selected parts of these assessments on indication alongside vision screening, specifically for older drivers and those with vision difficulties. Programs to support independent mobility beyond driving are also needed.

There were no studies identified looking at cataract and driving performance despite this review finding one paper showing cataract surgery to improve driving performance. There was however substantial evidence about the negative impact of reduced contrast and glare sensitivity on driving performance, both common symptoms of cataract. Cataract surgery can decrease these driving difficulties by 88 %, (Subzwari et al., 2008) but driving at night or in low contrast visual acuity conditions can still remain difficult. (Mönestam and Lundqvist, 2006) Further, a driving simulation study on older drivers comparing their driving performance scores from before first eye to after second eye surgery only found significant improvements to the time spent speeding but not lane and speed deviations. (Meuleners et al., 2021) Others have proposed that improvements to driving may be due to the type of intraocular lens implanted and its blue light filtering feature may impact how much driving improves but research on this area is currently inconclusive. (Beiko, 2015; Espindle et al., 2005; Gray et al., 2012; Wright et al., 2017).

This review found 33 different ways driving errors and performance can be measured on on-road driving circuits, thus making it difficult to determine which measure impacts driving safety, particularly crash involvement. Reporting the number of driving errors was the most commonly used measure. This makes sense as naturalistic driving data has shown driver errors, impairment, fatigue and distraction, to be responsible for almost 90 % of crashes. (Dingus et al., 2016) A study on the naturalistic driving habits of older drivers found impaired contrast sensitivity or moderate and severe slowing of visual processing speed to increase crash risk by 2.7, 2.3 and 5 times, respectively. (Swain et al., 2021) A recent study combining naturalistic driving data and on-road driving performance of older drivers found those with worse scores on the on-road circuit to be 2.8 times more likely to get into both at-fault and near-crashes than those with better scores after adjusting for age. (Swain et al., 2021) However other surrogate measures of performance such as course completion time and reversing time have yet to be connected with crash involvement. Future research looking into the harmonisation of outcome measures could be of benefit to the field. One such example is the "P-drive" assessment tool which tests a range of skills from vehicle position to stimuli responses, and has been used clinically and validated by occupational therapists. (Patomella and Bundy, 2015).

There a few limitations in this review that need to be acknowledged. Firstly, this review only includes 27 studies despite searching from three, large electronic databases. This might be because the scope was restricted to on-road driving. It is also a limitation that there are few studies from LMICs. Further, due to the variability in driving performance measures, *meta*-analysis was not feasible. Narrative summaries were used instead however these summaries are restricted by the studies' methodological limitations. Sample sizes in the included studies were small as individuals with a vision impairment may deem participation to be too risky. Studies also used different on-road circuits and scoring of performance measures varied from relying on either a driving instructor, a driver-trained occupational therapist or both. As there were no studies from LMICs identified, the results from this review may hold limited relevance in these countries. This is of concern as, despite legislation promoting safe driving in these countries, the practice-knowledge gap amongst drivers contribute to high crash and road injury rates in LMICs. (Anebonam et al., 2019; Chen, 2010; Chen et al., 2016; Damsere-Derry et al., 2017; Jothula and Sreeharshika, 2021; Mohamad et al., 2019; Ngueutsa and Kouabenan, 2017; Staton et al., 2016) Research is needed to understand this gap and the factors surrounding how drivers in LMICs interact with the road system. Nonetheless, the strengths of this review includes the breadth of different eye diseases and vision-related interventions on numerous different driving performance measures. There were also no restrictions on age which therefore allowed the evidence on the driving ability of younger and or middle-aged drivers with a vision impairment to be documented. With all but two of the studies being published within the past two decades, this review nonetheless provides a comprehensive overview of this growing area of research.

Conclusions

In conclusion, this review summarises the global literature on the impact of vision and vision-related interventions on driving performance as part of the *Lancet Global Health Commission* on Global Eye Health. Glaucoma, AMD, monocularity, self-reported vision loss and declines in contrast sensitivity, visual acuity, glare sensitivity and visual field were shown to negatively impact a variety driving performance measures, while cataract surgery or appropriate corrective lenses can improve driving scores and reduce errors on hazard and signage recognition. Current literature, however, is highly heterogeneous, and contains few interventional studies and no studies from LMICs. Future studies should aim to address these gaps in order to inform investments in health care services directed at eye care to help reach the UN's SDGs on creating a safer driving environment.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

Acknowledgements

None.

Data sharing

All data collected for the study have been provided in the submitted supplementary tables and will be made available at the time of publication with the journal. The study protocol was previously published and is publically available (10.1136/bmjopen-2020-040881).

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.trip.2022.100753.

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