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Big Data Analysis of Vision Screening Standards Used to Evaluate Fitness to Drive

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Dublin Research Ethics and Integrity Committee (contact via researchethics@tudublin.ie) for researchers who meet the criteria for access to confidential data.

Abstract:

Purpose:

Visual acuity assessment is the most commonly performed vision screening method for drivers. The standards and repeat assessment intervals used, however, are arbitrary, lack an evidence base and are highly variable across different countries. This study utilises the power of Big Data to provide evidence-based recommendations for standardised driver vision screening.

Methods:

Anonymised electronic medical record data was gathered from 40 Irish optometry practices comprising 81,184 unique patients. A Kaplan-Meier Survival (KMS) analysis was used to determine the effect of increasing age and time since screening on the likelihood of passing the visual acuity standard for driving. A logistic function was fit to assess the effect of varying the minimum visual acuity standard required to drive on the screening pass rate within the population.

Results:

The likelihood of failing repeat screening increased as a function of time since initial screening for all age groups (χ^2=1447, df=6, p<0.001), with older patients most affected. Rescreening intervals for individuals who initially met the vision standard unaided reduced as a function of age. Using an 80% survivability threshold, intervals ranged from every eight years for drivers under 50, reducing to every two years for those aged over 80. Rescreening intervals for drivers requiring optical correction to meet the standard, also decreased with age. Approximately 1% of individuals are excluded from driving using a 0.3 logMAR visual acuity standard with correction.

Conclusion:

Visual acuity-based screening should take place at regular intervals for all drivers, not just those over 70. Re-screening intervals should be based on age, with shorter intervals for older drivers due to the combined effect of age and time on the likelihood of passing the driving visual acuity standards. The most commonly used standard of 0.3 logMAR results in a minimal number of potential drivers being excluded from driving.

Introduction:

The ability to drive safely is complex, involving detailed sensory, cognitive and motor factors which have to be integrated and enacted within a limited timeframe.[1] Vision provides the most important sensory input when driving and several studies have linked various forms of reduced vision with increased traffic collisions.[2,3] Vision loss has also been associated with decreased cognition in older adults,[4] itself a factor for road traffic crashes.[5] There is conflicting evidence, however, regarding the influence of commonly tested aspects of vision such as visual acuity (VA) and visual field on driving performance.[6,7] Furthermore, there is a distinct paucity of high quality evidence exploring the relationship between mandatory vision screening and driver safety.[8] Nevertheless, most countries require evidence that vision meets a pre-defined standard in order to be legally permitted to drive.

The vision screening standards used for driving vary widely across different countries, including in Europe. The European regulatory directives on driving licences (EC Directives 2006/126/EC and 2009/113/EC)[9] required harmonisation of driving licence vision screening standards by 2013, however this has not taken place. A wide spectrum of vision standards persists, therefore, varying from licence plate figure recognition tests carried out by non-qualified driving test employees in some countries, to a full vision and ocular health assessment carried out by an ophthalmologist in others. Currently the primary method by which vision is assessed to determine suitability for driving is by measuring visual acuity, but the level required to be eligible to drive is country specific. The most common minimum standard with or without optical correction required in Europe is binocular acuity of 0.5 decimal (0.3 logMAR, 6/12 (20/40) Snellen), although this varies from 0.0 logMAR in Italy and Turkey to identifying figures on a licence plate at a specified distance in countries such as the Netherlands and the United Kingdom,[10] an approach which does not compare favourably to the use of vision charts.[11] The use of licence plates places the responsibility on drivers to self-assess their vision however it has been found many drivers do not recall the correct distances at which to conduct this self-assessment.[12] Many countries set visual field requirements, the most common of which is that the field extends to 120 degrees horizontally,[10] while others also require additional vision assessments such as colour vision, contrast sensitivity and glare recovery although it is unclear how frequently these additional assessments are performed.[10] Another significant source of variance in standards across countries relates to the frequency of repeat screening. Some jurisdictions require repeat screening every 10 years up to age 70 (and more frequently thereafter), while others place the responsibility on the driver themselves to self-report any changes in their vision, with no mandatory screening after the initial assessment until age 70.[10]

Driver vision screening standards have been criticised as lacking an adequate evidence base,[13,14] a view that appears justified by the apparent lack of consensus demonstrated between countries. Irrespective of whether visual acuity is a good indicator of driver safety, the clinical implications of the substantial variation in existing standards merits investigation. In Ireland, mandatory vision screening takes place when initially applying for a licence (minimum age 16 for motorcycles; 17 for cars). No further screening is required until the driver reaches the age of 70, after which vision is assessed at 3-year intervals at each licence renewal. Screening is conducted by registered optometrists or medical doctors, with applicants needing to meet the most common standard for visual acuity of 0.3 logMAR, either with or without correction.

This study was designed to examine the suitability of driver vision screening standards as currently used in Ireland and many other European countries to determine fitness to drive. Specifically, EMR data derived from optometric practices involved in the routine measurement of visual acuity (e.g. as part of routine driver vision screening and refractive error management) was initially used to assess how uncorrected and corrected visual acuity vary as a function of age within the population. Subsequently, the EMR data was analysed using a machine learning approach to examine: (i) what effect does variation in the legal visual acuity threshold have on the probability of failing the vision standard even with correction; and (ii) how does age and the length of time between vision tests influence the probability of meeting the required vision standard for driving at a subsequent vision test, after initially meeting the standard either with or without correction. These analyses were used to develop evidence-based recommendations regarding the frequency of driver vision screening and threshold acuity level required to be legally permitted to drive.

Methods:

Anonymised EMR data was gathered from 40 Irish optometry practices. The data was extracted remotely through the EMR provider following provision of explicit consent from the data (practice) owners during the period of May 2018 to June 2020 for all 40 practices. The data extracted comprised all practice records since first use up to the date of extraction for each practice. The EMR provider removed any personally identifying data and anonymised the data prior to delivery so that the anonymisation could not be reversed by the researchers. The data was provided in multiple CSV files which were combined using the SQLite database engine V 3.30.00 (Hipp, Wyrick & Company, Inc., Charlotte, North Carolina, USA) with further analysis carried out using the R programming language (R Core Team (2020). R: A language and environment for statistical computing. R

Foundation for Statistical Computing, Vienna, Austria. https://www.R-project.org/). At the time of extraction, a new unique identifying number was generated within the EMR data allowing individual subject data to be tracked across multiple visits. The data available for each individual clinical practice patient included demographic, refractive, visual acuity, binocular vision, contact lens, ocular health and clinical management data. For this analysis, only demographic, refractive and visual acuity data were considered. This study was approved by the Research Ethics Committee of the Technological University of Dublin and adheres to the tenets of the Declaration of Helsinki.

A custom function was written to remove erroneous visual acuity values and convert all Snellen and decimal uncorrected visual acuity (UCVA) and corrected visual acuity (CVA) values to logMAR notation. All patient records without complete and interpretable visual acuity data for both UCVA and CVA were excluded from the analysis. Patient visits under the age of 21 were also excluded from the analysis to specifically capture individuals most likely to drive. Patient visits were grouped in 10-year age intervals up to age 80, with all those aged over 80 grouped together due to the smaller number of patient visits. The average level of UCVA and CVA for each age group was calculated. The effect of age group on both UCVA and CVA was also assessed using the Kruskal-Wallis rank sum test.

Given the most widely adopted standard for visual acuity as it applies to driving is 0.3 logMAR, this was used as a reference to categorise measured UCVA and CVA according to vision standards criteria. A visual acuity of ≤ 0.2 logMAR in either eye was considered a pass, a visual acuity of > 0.2 logMAR and ≤ 0.4 logMAR in both eyes considered borderline and a visual acuity of > 0.4 logMAR in both eyes considered a fail. The proportion of visual acuity measurements in each visual acuity category and age group was determined for both CVA and UCVA. Subsequent analyses relating to vision standards were conducted separately for those without visually significant refractive error who passed based on their initial presenting UCVA and for those with refractive error who required optical correction to meet the standards based on CVA.

A Kaplan-Meier survival (KMS) analysis was used to determine the survival time before patients that initially passed the UCVA standard (≥ 0.3 logMAR in either eye) would fail the standard in a subgroup of patients that attended for multiple visits at least six months apart and were observed to pass the UCVA standard at their first visit. Patients were categorised into age groups according to their age at the initial visit. Right censoring was used in order to account for patients that never failed the UCVA standard over their observation period. The log-rank test was used to compare the survival curves for each age group.

To determine the effect of changes in refractive error on the likelihood of passing the standard in those using optical correction, the KMS analysis was repeated for a subgroup of patients that were found to: (i) be myopic (right eye spherical equivalent refraction (SER) ≤ -0.50 D) or hyperopic (right eye SER ≥ +0.75 D) at their first and subsequent visits (without regression towards emmetropia at subsequent visits); (ii) failed the standard based on UCVA, but passed the standard based on CVA with correction; and (iii) had multiple visits at least six months apart. Progression of refractive error was analysed in these patients over time, and the calculated progression was used to provide an estimate of change in visual acuity, with a deterioration of 0.3 D SER assumed to be equivalent to a 0.1 logMAR deterioration in CVA if the original optical correction used to pass the initial vision screening was not updated.[15] These patients were considered to have failed the standard when their estimated change in visual acuity resulted in a new estimated CVA greater than 0.3 logMAR (necessarily assuming that spectacle correction was not updated). For the purposes of this analysis, accommodation effects were ignored. The log-rank test was used to compare the survival curves for each age group.

The KMS analysis was also used to determine optimised repeat vision screening intervals for both the UCVA and CVA standards. This involved determining vision screening intervals as a function of the proportion of the population expected to still pass the UCVA or CVA standard. The time between visits was assessed for those with refractive error to determine if the frequency of repeat eye exams was less than the KMS analysis recommended repeat vision screening intervals for the UCVA standard.

To determine an appropriate visual acuity standard, the number of patients that would pass at different acuity threshold levels with and without correction were assessed. The thresholds used followed the typical Snellen chart letter size progression (the most commonly used chart type in clinical practice). A logistic function was fit to the percentage of patients passing at each acuity standard.

Results:

The original data set comprised of 697,098 practice visits of 288,777 unique patients, representing 5.9% of the population of the Republic of Ireland.[16] The 40 participating optometric practices were located all across the Republic of Ireland comprising both rural and urban populations. After excluding patients under age 21 and with incomplete data, 154,824 practice visits of 81,184 unique patients remained. The absence of either UCVA or CVA values was the primary reason for exclusion, accounting for 96.7% of records removed. The gender distribution was 54.7% female, 37.9% male and unrecorded in 7.4% of records. The mean age was 49.6 ± 21.1 years.

The mean right eye UCVA was 0.35 ± 0.36 logMAR while the mean right eye CVA was 0.01 ± 0.15 logMAR (females: UCVA 0.35 ± 0.36, CVA 0.01 ± 0.15; males: UCVA 0.33 ± 0.36, CVA 0.01 ± 0.16). Gender was found to have a statistically significant effect on both UCVA (t = -11.55, df = 167051, p-value < 0.001) and CVA (t = -4.89, df = 167051, p-value < 0.001), however this was likely due to the large sample size as the difference in the means were not considered clinically significant. There was higher variability of UCVA when compared to CVA across all age groups, a likely reflection of the range of refractive errors that affect individuals of all ages (Supplemental Figure 1). Additionally, both UCVA and CVA deteriorated with increasing age, with an obvious reduction in CVA from the seventh decade onwards (Supplemental Table 1). The effect of age group was statistically significant for both UCVA (χ^2 = 8225, df = 6, p-value < 0.001) and CVA (χ^2 = 18241, df = 6, p-value < 0.001). Pairwise comparisons using Dunn's test indicated significant differences between every age group (p < 0.001 for all).

The relative proportions of VA measurements falling into each vision standard category (pass, borderline and fail) were observed to vary as a function of age for both UCVA (χ^2 = 4555, df = 2, p-value < 0.001) and CVA (χ^2 = 2349, df = 2, p-value < 0.001). An increasing percentage of measurements fell into the borderline and fail categories with increasing age, particularly for UCVA (Supplemental Figure 2). Over 40% of VA measurements were categorised as failing or borderline according to UCVA, while less than 2% of VA measurements were similarly categorised for CVA, primarily among older drivers aged over 70.

Longitudinal Analysis – Uncorrected Visual Acuity

In total, 23,393 patients who initially passed the vision standard with UCVA were eligible for inclusion in the longitudinal analysis. The mean time between visits was 1.86 ± 2.12 years, with a mean total follow up time of 3.62 ± 3.76 years. For patients with longitudinal data, the mean annualised change in UCVA and CVA was 0.022 ± 0.531 logMAR per year and 0.003 ± 0.157 logMAR per year respectively.

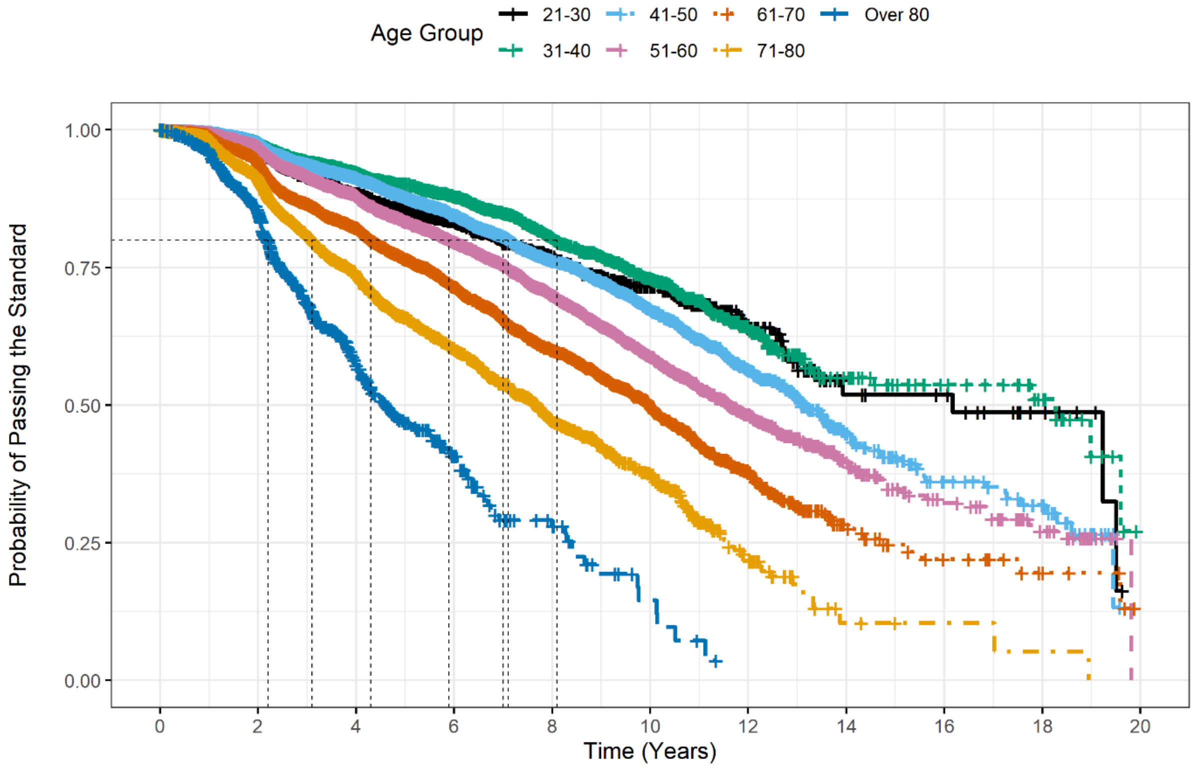
The KMS analysis revealed that increasing time since the initial visit was found to negatively affect the likelihood of passing at subsequent visits. Older initial age was also found to negatively affect the likelihood of passing at subsequent visits (χ^2 = 1447, df = 6, p-value < 0.001). Reassessment intervals determined using the KMS analysis were observed to vary according to different survivability threshold levels across each age group (Table 1), with lower threshold values (e.g. 50% survivability where just half the population will be expected to still meet the standard) resulting in long reassessment intervals for all age groups, and high thresholds (e.g., 90% survivability where most of the population will be expected to still meet the standard) requiring frequent reassessment intervals for all.

Table 1: Reassessment intervals needed in order for a given proportion of the population to still pass the uncorrected visual acuity (UCVA) standard

Age Group (years)	**RI for 90% Pass Rate (years)**	**RI for 80% Pass Rate (years)**	**RI for 75% Pass Rate (years)**	**RI for 70% Pass Rate (years)**	**RI for 50% Pass Rate (years)**
21-30	3.6	7.0	8.5	10.5	16.2
31-40	5.1	8.1	9.5	10.7	18.3
41-50	4.0	7.1	8.5	9.6	13.1
51-60	3.4	5.9	7.1	8.0	11.6
61-70	2.3	4.3	5.4	6.2	10.0
71-80	2.1	3.1	3.8	4.4	7.7
Over 80	1.5	2.1	2.5	2.9	4.6

Abbreviations: RI, Reassessment Interval

Figure 1 illustrates the relationship between initial age and time since first visit on the likelihood of passing. All age groups were negatively affected by increasing time since first visit. Using a survivability threshold of 80% (i.e., 80% of individuals still pass the standard), survival time reduced as a function of age, with older age groups exceeding the threshold at progressively shorter intervals, dropping from an expected survival time of 8 years for patients in their 30s, to just over 2 years for those aged over 80.



Number of Patients at Risk of Failing the Standard

Age Group	0	2	4	6	8	10	12	14	16	18	20
21-30	1458	1183	743	511	348	209	75	20	17	7	0
31-40	2427	2109	1472	1082	725	434	167	52	30	16	0
41-50	5982	5224	3513	2458	1622	916	353	95	40	24	0
51-60	5962	5237	3563	2568	1680	916	336	97	47	24	0
61-70	4263	3594	2389	1589	980	488	178	33	14	6	0
71-80	2523	1937	1111	657	346	156	31	4	2	1	0
Over 80	778	495	183	65	24	6	0	0	0	0	0

Time (Years)

Figure 1: Kaplan-Meier curves demonstrating the reducing likelihood of passing the standard in a cohort of individuals that initially passed the standard with uncorrected visual acuity (UCVA). Increasing time since the initial vision assessment reduces the likelihood of passing for all age groups. The dotted lines indicate the time interval for each age group by which 80% of individuals will still pass the UCVA standard.

Reassessment intervals to achieve an approximate 80% survivability are provided in Table 2, which also illustrates the expected survivability rates for the most common re-screening criteria currently used in countries where periodic rescreening is required (rescreening every 10 years until age 70). This analysis demonstrates a progressive age-related decrease in survivability from 71% among the youngest drivers to just 50% after 10 years among those aged 61-70. For the youngest drivers, just 17% are expected survive after 20 years (the longest period available for analysis within this data), long before the most common mandatory rescreening at age 70.

Table 2: Reassessment intervals required to achieve an approximate 80% survivability rate based on uncorrected visual acuity (top panel) compared to survivability rates for the most commonly used screening intervals used in countries that require regular vision screening (bottom panel).

Reassessment Intervals Based on 80% Survivability		
Age Group (years)	**Reassessment Interval (years)**	**Percentage Expected to Pass**
21-30	8	77%
31-40	8	80%
41-50	8	76%
51-60	6	80%
61-70	4	82%
71-80	3	81%
Over 80	2	86%
Common Reassessment Intervals		
Age Group (years)	**Reassessment Interval (years)**	**Percentage Expected to Pass**
21-30	10	71%
31-40	10	73%
41-50	10	67%
51-60	10	59%
61-70	10	50%
71-80	3	81%
Over 80	3	68%

Longitudinal Analysis – Corrected Visual Acuity

There were 9,209 myopic patients and 15,155 hyperopic patients that met the inclusion criteria for longitudinal analysis. For the myopic subgroup, the mean time between visits was 2.89 ± 2.15 years, with a mean total follow up duration of 5.02 ± 3.32 years. For the hyperopic subgroup, the mean time between visits was 2.79 ± 2.03 years, with a mean total follow up duration of 5.37 ± 3.42 years. Reassessment intervals were observed to vary according to different survivability threshold levels across each age group for the myopic and hyperopic cohorts in a similar way to the uncorrected cohort, with low survivability thresholds requiring longer reassessment intervals and high survivability thresholds requiring shorter reassessment intervals (Table 3).

Table 3: Reassessment intervals needed in order for a given proportion of the population to still pass the corrected visual acuity (CVA) standard

Age Group (years)	RI for 90% Pass Rate (years)	RI for 80% Pass Rate (years)	RI for 75% Pass Rate (years)	RI for 70% Pass Rate (years)	RI for 50% Pass Rate (years)
Myopia (SER ≤ -0.50 D)					
21-30	3.2	4.1	4.4	4.6	6.2
31-40	3.8	4.6	5.1	5.9	8.6
41-50	3.8	4.8	5.4	6.1	8.3
51-60	3.6	4.6	4.9	5.7	8.0
61-70	2.9	4.1	4.7	5.2	7.8
71-80	2.2	3.5	4.1	4.5	7.7
Over 80	2.1	3.2	3.8	4.5	7.5
Hyperopia (SER ≥ +0.75 D)					
21-30	2.3	3.5	3.8	3.9	5.6
31-40	3.3	4.5	5.3	5.7	7.6
41-50	3.3	4.2	4.5	4.9	7.0
51-60	3.6	4.6	5.1	5.7	8.0
61-70	3.5	4.4	4.8	5.4	7.8
71-80	2.8	3.8	4.1	4.5	6.5
Over 80	2.1	3.2	3.7	4.2	6.8

Abbreviations: RI, Reassessment Interval; SER, Spherical equivalent refraction; D, dioptre

The mean reassessment interval for both the myopic and hyperopic cohorts to achieve 80% survivability was 4.1 years. Figures 2 (myopic subgroup) and 3 (hyperopic subgroup) demonstrate the relationship between initial age and time since first visit on the likelihood of continuing to pass the standard. All age groups were negatively affected by increasing time since first visit. For the myopic subgroup, there was a statistically significant difference in the risk of failing between all age groups (χ^2 = 159, df = 6, p-value < 0.001). This was also the case for the hyperopic subgroup (χ^2 = 51.2, df = 6, p-value < 0.001). Older age groups were likely to fail the standard in the shortest time, although the difference between age groups was not as great as that found for the UCVA group.

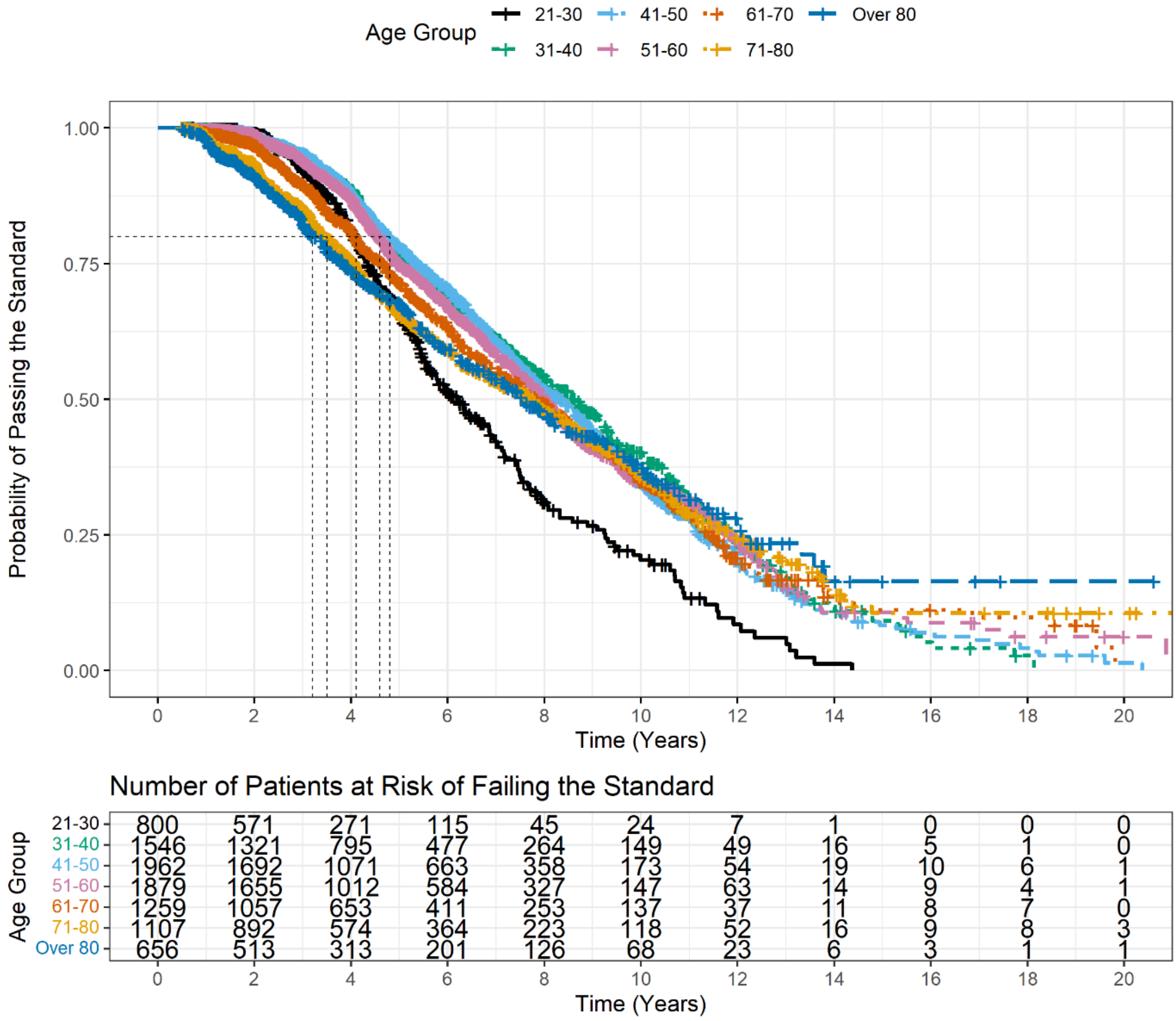


Figure 2: Kaplan-Meier curves demonstrating the reducing likelihood of passing the standard in a cohort of myopic (right eye SER ≤ -0.50 D) individuals (n = 9,209) that initially passed the standard with corrected visual acuity (CVA). Increasing time since the initial vision assessment reduces the likelihood of passing for all age groups. The dotted lines indicate the time interval for each age group by which 80% of individuals will still pass the CVA standard if their refractive error correction is not updated.

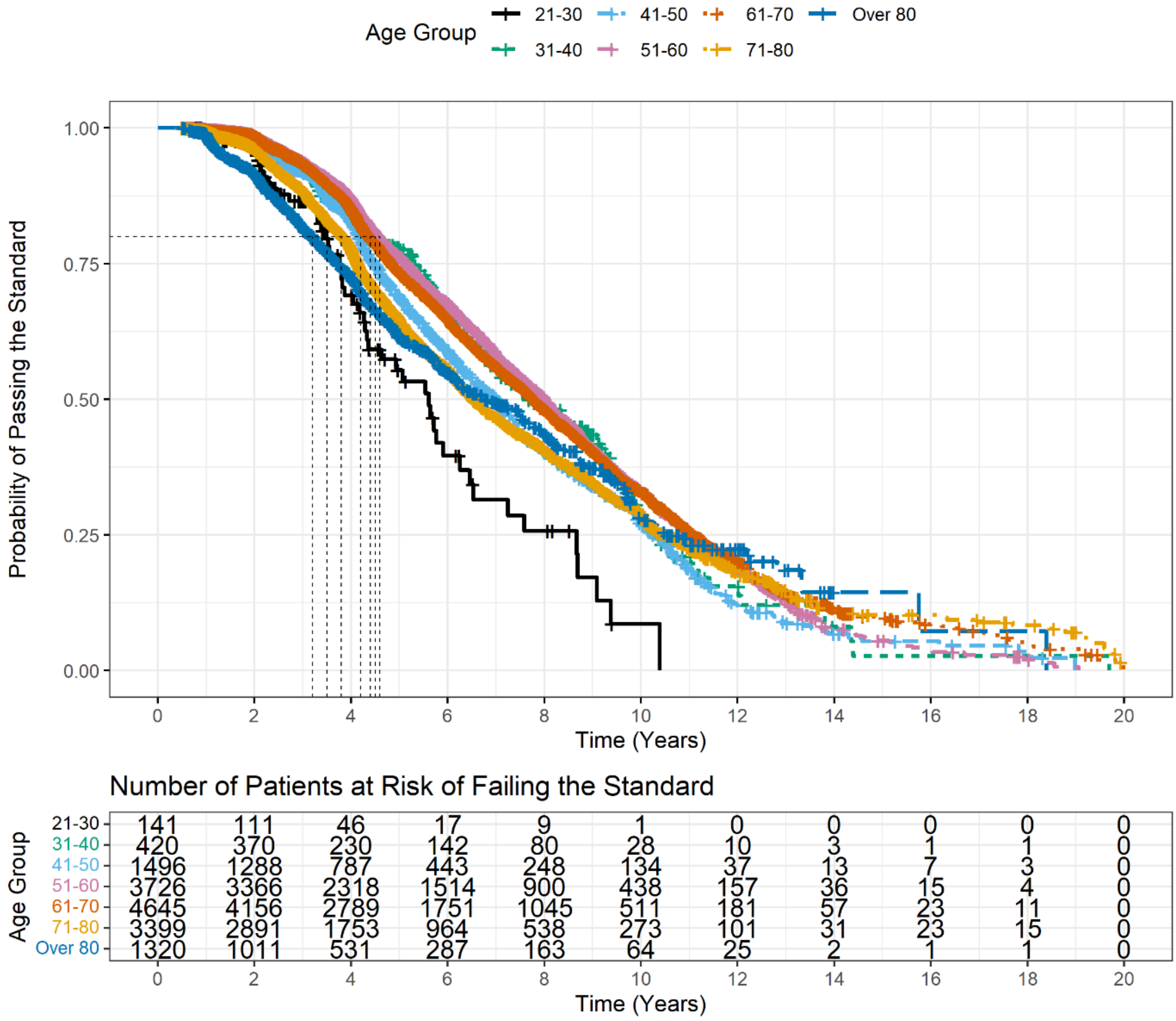


Figure 3: Kaplan-Meier curves demonstrating the reducing likelihood of passing the standard in a cohort of hyperopic (right eye SER ≥ +0.75 D) individuals (n = 15,155) that initially passed the standard with corrected visual acuity (CVA). Increasing time since the initial vision assessment reduces the likelihood of passing for all age groups. The dotted lines indicate the time interval for each age group by which 80% of individuals will still pass the CVA standard if their refractive error correction is not updated.

Figure 4 shows the time between eye exam visits for both male and female patients in the myopic and hyperopic groups. The significant majority of visits occurred within 1-3 years of the previous visit, with just 16.4% of visits occurring at intervals greater than the respective 80% survivability threshold intervals across all age groups. There was no statistically significant difference in the time between visits for female and male patients (Wilcoxon signed-rank test; W = 62674901, p = 0.52).

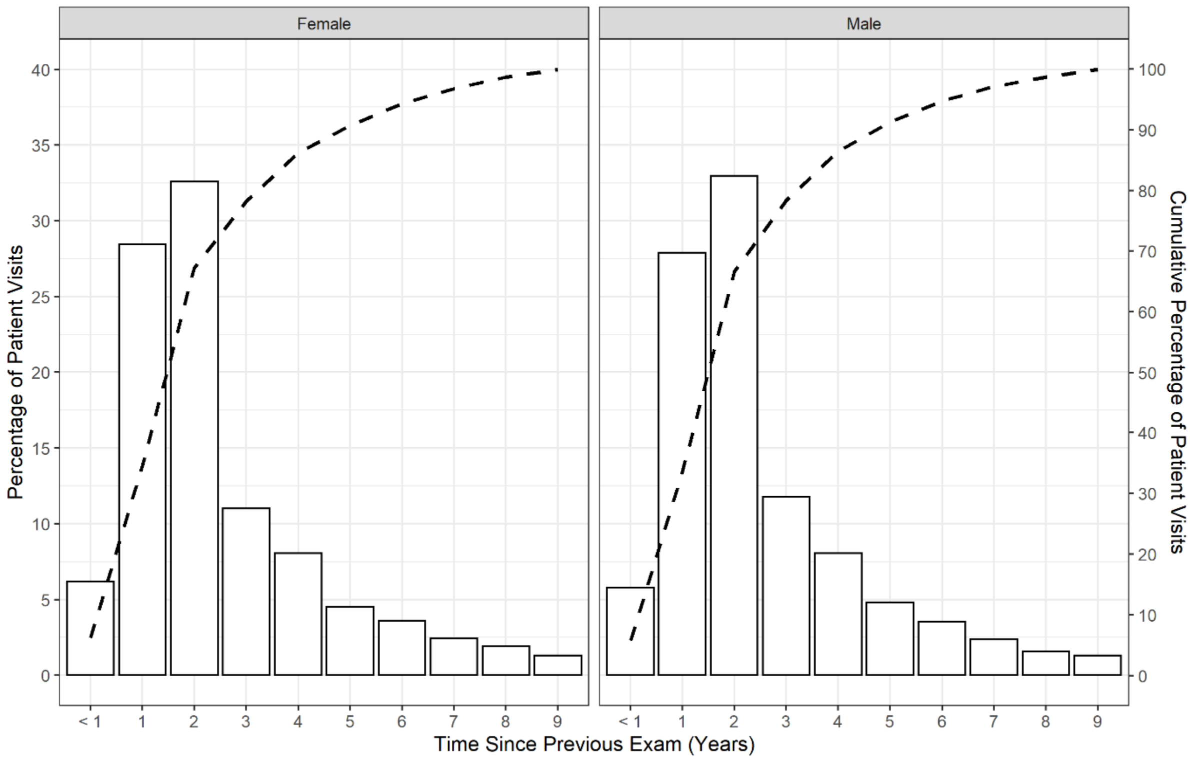


Figure 4: Time between eye exams for female and male patients with refractive error (SER ≤ -0.50 D or SER ≥ +0.75 D). Cumulative percentage shown by dashed line.

Figure 5 shows the percentage of patients that would pass at various thresholds for the binocular CVA standard. At a low CVA threshold of 1.0 logMAR (6/60 Snellen), almost 100% of patients pass the standard, irrespective of age. The proportion of patients passing reduces only marginally (≈1%) when the threshold is increased to the most commonly used standard of 0.3 logMAR (6/12 Snellen). Increasing the threshold further results in a more significant number of patients failing the standard, with 12% failing at the 0.0 logMAR (6/6 Snellen) standard (estimate = -1.6, t = -9.0, $p < 0.001$).

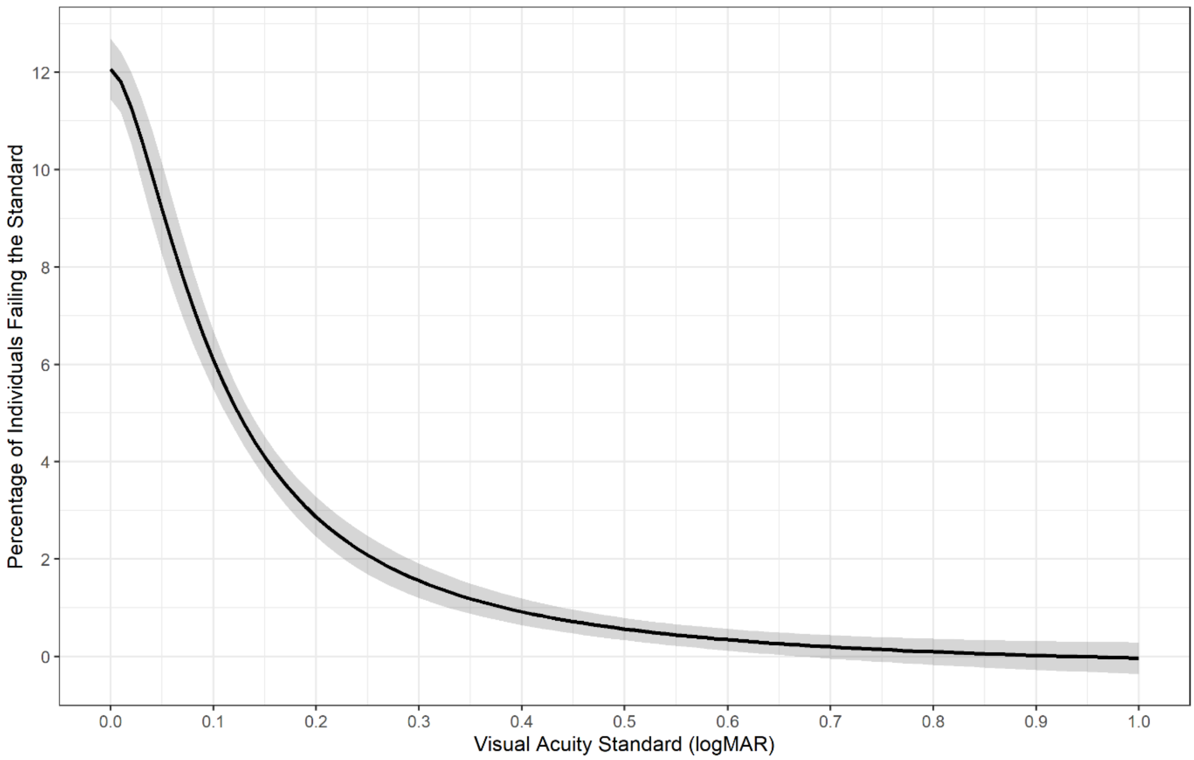


Figure 5: Logistic function demonstrating the age-independent change in percentage of patients that fail the binocular visual acuity standard (even with correction), when the threshold is varied between 0.0 and 1.0 logMAR

Discussion:

This study exploited a sizeable EMR dataset containing detailed cross sectional and longitudinal UCVA and CVA data for the purposes of evaluating visual acuity thresholds as a legal driving standard. The finding that the most commonly used visual acuity threshold (0.3 logMAR (6/12 Snellen) excludes just a small minority of potential drivers is important for a number of reasons. It is well established that the cessation of driving in older drivers is associated with increased rates of depression[17,18] through loss of independence and steeper declines in general health.[19] Given that older drivers are most likely to experience reducing visual acuity, it is important to set standards at a level which does not unfairly bias screening against older drivers. This must, however, be weighed against the increased risk potentially posed to other road users by those with reduced vision.[20] The available evidence pertaining to the relationship between visual acuity and driver safety is somewhat conflicting, with some studies suggesting no relationship,[21,22] while others have found a small but statistically significant relationship.[6,23] A recent meta-analysis of vision function and traffic safety outcomes in low and middle income countries observed a 46% increased risk of traffic crash in those with visual acuity of ≤ 6/18 Snellen (≥ 0.48 logMAR),[24] adding to the evidence base that reduced visual acuity contributes to risk of traffic crashes. The lack of definitive evidence is not surprising given that concomitant reductions in other aspects of visual function such as contrast sensitivity, visual field and useful field of view may also impact driver safety and are not necessarily captured by visual acuity measures.[25,26] It is important to have a measure of visual performance, however, as diminishing visual function has been shown to negatively impact both driver safety and driver performance.[26]

Irrespective of whether visual acuity provides the best index of driver safety or performance, several factors dictate that visual acuity standards are likely to persist as a core component of driver vision screening. It does capture certain visual requirements for driving such as road sign recognition and hazard avoidance.[27] Additionally, visual acuity screening is the most commonly performed and widely understood method for assessing vision, requires relatively little specialist equipment or training, and is widely enshrined in policy and legislation as an accepted means of classifying vision (e.g. legal classification of a patient as vision impaired or blind). Setting the standard at 0.3 logMAR ensures that up to 99% of potential drivers can comfortably be expected to pass this commonly used visual acuity standard for driving. This is the standard currently used in Norway and Sweden, which have some of the lowest road deaths per vehicle distance travelled in Europe.[28] Other countries with more stringent visual acuity standards (which would prevent a higher percentage of people from driving) have substantially poorer road death statistics,[28] suggesting that other factors may be more important determinants of driver safety. Uncertainty regarding the importance of visual acuity for driver performance[27,29] and safety,[26] coupled with the established association between driving cessation and poor health outcomes, suggests there is limited value in setting the standard at a threshold value which might unnecessarily exclude a significant percentage of people from driving without any supporting safety evidence. A 0.3 logMAR standard, therefore, appears a balanced and fair threshold which virtually all (≈99%) drivers will meet either with or without correction in the absence of significant ocular disease or other cause of reduced CVA.

Another key finding from this Big Data analysis is that the frequency of driver vision screening assessments appears to be inappropriately long for younger drivers in Ireland and many other European countries. Exploring the relationship between time since initial screening, age and the likelihood of passing the standard for individuals who originally met the standard unaided revealed that the likelihood of passing reduced with time for all age groups, not just for elderly drivers. With an average reduction in UCVA of +0.022 logMAR per year, a driver who initially passed the standard unaided would lose approximately 2-3 lines of visual acuity over a 10-year licence renewal period, which could result in an individual changing from the comfortably passing category to the borderline or fail category without correction. Furthermore, in the myopic subgroup, the youngest drivers included herein (age 21-30) were found to have the fastest reduction of UCVA of all potential drivers, likely due to increased myopic progression in this age cohort.[30] The current standards adopted in many countries, where repeat visual function assessments are only required when individuals reach a certain age, usually over the age of 70,[10] would fail to detect such drivers and instead have to rely on driver discretion with respect to their ability to see sufficiently well to drive in all conditions. In such countries, drivers are expected to self-regulate, recognise and report changes in their vision. This raises the possibility of lengthy gaps between vision screening assessments, particularly for drivers who do not wear optical correction and therefore do not routinely attend an eye care practitioner. This is contrary to public preference, with a 2014 study finding that 87% of those surveyed thought drivers should have to provide evidence of meeting the vision standard when renewing their licence.[31]

The age-related decrease in CVA and sizeable reductions in likelihood of passing the vision standard observed among older individuals herein suggests that more frequent vision screening in older drivers is justified. In most countries, older drivers, usually over the age of 70, are already required to undertake regular vision screening at each licence renewal.[10] There is little evidence to support the idea that targeting elderly individuals for vision screening reduces the risk of motor vehicle crashes.[8] Increased frequency of screening of this age cohort seems sensible, however, given that the prevalence of many of the major causes of vision impairment and blindness such as cataract, glaucoma and age-related macular degeneration is highly age-dependent.[32–34] Both UCVA and CVA were observed to deteriorate with increasing age and over time herein, evidenced by the increasing proportion of older individuals falling into the borderline and failing vision standard categories. Among individuals that initially met the standard without correction, the likelihood of passing a future vision screening unaided therefore reduced over time. These findings are not unexpected as it is well established that visual function diminishes with age,[35] but they provide solid evidence to support a requirement that screening protocol should be age-specific.

Our analyses suggest that separate vision screening protocol should be considered for those who meet the standard unaided and those who require optical correction to drive. Rescreening intervals were notably shorter at every survivability threshold for those requiring refractive error correction, particularly among younger drivers under the age of 50 who would have to be screened every 4-5 years to meet an 80% survivability criterion. Drivers who initially meet vision standards unaided may subsequently fail due to pathology, or more likely due to the development of new refractive error or loss of acuity over time due to the progressive manifestation of latent hyperopia. Based on our observations herein, this gradual decline in UCVA appears to be slower than the change in CVA affecting drivers who require optical correction to meet the standard. It is likely that the reduction in CVA is due to progression of existing refractive error in most cases, which may lead individuals to fall below the standard more quickly if their correction is not updated routinely. Such individuals, however, are typically under the care of an eyecare practitioner and likely to attend for regular review eye exams.[36] The majority of individuals with refractive error requiring optical correction in our dataset attended for repeat visits within the recommended rescreening interval for their respective age group, so any deterioration in CVA is likely to be addressed for most drivers before CVA falls below the legal standard. Although the survivability data suggests the need for separate protocol, it seems reasonable to consider that a single protocol could be implemented. This would avoid the necessity to implement different screening protocol based on whether refractive correction is required to drive or not as long as specific provisions are incorporated to address the issue of poorer survivability among those who require correction to pass the CVA standard. The use of a single protocol would be a more realistically achievable approach given the apparent difficulties involved in implementing a single harmonised policy across Europe.

Rescreening intervals varied according to the selected survivability threshold. For those who initially meet the standard unaided, selecting a survivability threshold of 90% would require approximately biennial testing across many age cohorts. This would have huge resource implications and is unlikely to be a sustainable model. Lower thresholds at the level of 50% would require far less frequent screening, with the oldest drivers only requiring rescreening at 5-year intervals, which would lead to a scenario where half the population of drivers would no longer meet the vision standards by the time they are re-screened, which is certainly not desirable. Aligning re-screening intervals with driving licence renewals might make practical sense, and would certainly represent an improvement in countries like Ireland. A survivability threshold around 75 to 80% would appear to provide a reasonable compromise, with an interval between screening that remains relatively close to standard 10-year licence renewal periods up to age 50, but requires more frequent screening thereafter.

This study provides the most comprehensive analysis of driver vision standards completed to date. Particular strengths of the study include the large sample size and longitudinal nature of the data. The refraction and visual acuity data were acquired by highly trained optometrists which should represent high quality clinical data. Limitations of the study include the retrospective nature of the study. The data analysed was not captured specifically for this purpose, although it is unlikely that a prospective study of a similar scale would be feasible to conduct. It is unknown what proportion of the data in this study represents actual drivers or what proportion of patient examinations involved actual driver vision screening. However, over 75% of all adults in Ireland hold a valid driving licence,[37] and the data is certainly representative of adults eligible to undertake driver vision screening. Selection bias might be considered as a limitation given the clinical nature of the data analysed, as it is unknown what proportion of examinations were for the purpose of driver vision screening. This is unlikely to be a major concern herein, however, as most driver vision screening is conducted by optometrists in Ireland, so our dataset naturally contains a subset of such data. The large number of individuals with longitudinal data that maintained good UCVA for long periods of time (≥ 10 years) should mean the survival analysis is also representative of those with stable good UCVA. The dataset analysed also contained more female than male participants. This is not surprising as it has been found elsewhere that female patients are more likely to attend optometric services likely as a result of attitudinal differences on seeking health services between men and women.[38] Despite this difference the very large number of both female and male participants should ensure these results can be applied to both the adult male and female populations. All of the data analysed is specific to the Republic of Ireland which may be perceived to limit generalisability, but it is unlikely there are significant population differences in terms of change in UCVA or CVA over time across Europe. Refractive error has been found to vary with ethnicity, with much higher rates of myopia and faster progression observed in Asia.[39] This may mean the reassessment intervals calculated for CVA are not applicable in all parts of the world. These analyses also do not include a specific assessment of changes in visual field, an important parameter for fitness to drive, or other affects ocular pathology may have on the eye. The survival analyses conducted herein are influenced by individuals with conditions that affect vision, but the data was not available to evaluate their precise impact on vision over time. In high income countries such as Ireland with good access to eyecare, most patients in these categories will be under more regular review, however, this may not be the case in all countries. These results also apply to the most commonly used visual acuity criteria for driving of 0.3 logMAR which is the standard typically used for cars and motorcycles.[10] The standard for heavy goods vehicles and buses is usually more stringent, with more frequent reassessment required. This analysis does not apply to this cohort who represent a small proportion of drivers, accounting for less than 2% of the 200+ million total drivers in the European Union and for whom, stricter standards are already in place.[40] Lastly, the analyses contained herein represent an evaluation of the technical suitability of current visual acuity based driver vision screening standards. The findings do not relate in any way to driver safety, which would require a more significant body of prospective research to identify which battery of vision screening tools might provide the best indicator of individual fitness to drive. Indeed, a recent Cochrane review failed to find any suitably designed study which could evaluate the general efficacy of vision screening in reducing crashes,[8] so it is simply not possible, at present, to implement an evidence-based vision screening strategy based on safety data.

This Big Data powered analysis confirms that the commonly used 0.3 logMAR standard seems an appropriate threshold from an inclusionary perspective, and that regular visual acuity screening should be extended to include all drivers at age-appropriate intervals. To develop these findings into a harmonised protocol, key decisions would need to be made in relation to the chosen survivability threshold and in relation to the treatment of drivers who require optical correction, particularly if a single protocol was to be prioritised. Electronic medical record data derived from ophthalmic clinical practice has previously been validated as a useful epidemiological tool for refractive error.[41] This type of data represents an ideal resource to develop evidence-based recommendations for acuity-based driver vision screening standards, which might perhaps lead to a harmonised Europe-wide standard for driver vision screening.

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