Onset of, and recovery from, visual impairment: analysis of causes and consequences using the English Longitudinal Study of Ageing

Report to the Thomas Pocklington Trust

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This is the full report of a project which involved application of statistical techniques to analysis of a large national dataset. As a result the report is a technical one. The executive summary which follows gives an accessible summary of key findings and a fuller Pocklington's Research Findings summary can be accessed at www.pocklington-trust.org.uk

Summary

- This report examines the relationship between socioeconomic risk factors and the development of visual impairment in later life and the impact of change in visual acuity (both deterioration and improvement) on older people's lives (social engagement, economic position and wellbeing).

- Previous work has demonstrated that older people with visual impairments have high levels of co-morbidity, poverty, social exclusion, disability and low quality of life. However, most of this work has relied on cross-sectional analyses of associations between risk factors and the prevalence of a visual impairment. Causal mechanisms can be more convincingly identified using longitudinal data.

- The analysis presented here uses data provided by the English Longitudinal Study of Ageing (ELSA), a large multidisciplinary panel survey of a representative sample of people aged 50 and older in England that allows for an exploration of change in levels of visual acuity, factors related to such changes, and the social, personal and economic impacts of such change.

- ELSA uses a self-reported measure of visual acuity. To examine the validity of such an approach to measurement we analysed data from of The Irish Longitudinal Study of Ageing (TILDA). We conclude from this validation work that self-reported vision is a valuable and efficient measure of visual acuity.

- Analyses examining factors related to the risk of developing moderate and severe vision loss showed that both were strongly related to socioeconomic factors, with significantly higher risks for those with poorer wealth and with lower subjective social status, in fully controlled models.

- For example, those in the poorest wealth quintile had a more than 50% higher risk of onset of moderate visual impairment than those in the highest wealth quintile and an almost 80% higher risk for onset of severe visual impairment. While, after adjusting for wealth differences, those in the lowest subjective social status quintile had more than twice the risk of onset of moderate vision impairment than those in the highest quintile, and an 80% higher risk of onset of severe visual impairment.

- These socioeconomic inequalities were also identified when trajectories of visual acuity over an eight year period were examined. Decreasing levels of wealth were associated with a decreased probability of having an optimal vision trajectory (stable excellent or good vision) and increased probability of having a suboptimal trajectory (fair, poor or declining vision). And subjective social status had a significant additional effect beyond that already accounted for by material wealth.

- These findings demonstrate marked socioeconomic inequalities in both the onset of impaired vision and in the longer term patterning of change in visual acuity in later life.

- However, among those receiving a diagnosis of cataract, socioeconomic factors were not related to the future likelihood of having surgery. The implication is that, unlike for the situation in insurance-based health care systems, the NHS provides equitable access to cataract surgery.

- Health related factors – smoking, diabetes and hypertension – were also all related to increased risk of onset of moderate and severe visual impairment.

- Changes in visual acuity, both deterioration and improvement in vision, were related to changes in levels of wellbeing (depression and quality of life), social engagement and income over a two year period. Stronger associations with these outcomes were present for deteriorations in vision than improvements in vision.

- The largest effects were found for those whose vision deteriorated from optimal (excellent, very good or good) to suboptimal (fair or poor). For example, such a change led to a 29% rise in the number of depression symptoms, and a 19% fall in income, over a two year period. However, the size of these effects was reduced in fully adjusted models.

- Although effects were smaller, improvements in vision were associated with significant improvements in outcomes, especially for social engagement and quality of life.

- These findings provide strong evidence on socioeconomic inequalities in risk of visual impairment. And strong evidence on the relationship between change in vision and wellbeing, social and economic outcomes.

- There is, therefore, a clear need for policy to focus on strategies to minimise socioeconomic risks for deterioration in visual acuity, to ensure equitable access to treatments to address visual impairment, including easy and free access to corrective lenses, and to mitigate the negative effects of developing visual impairment.

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1. Introduction

This report sets out to understand socioeconomic risk factors for the development of visual impairment in later life and the impact of change in visual acuity (both deterioration and improvement) on older people's lives (social engagement, economic position and wellbeing). It places a particular focus on socioeconomic inequality and how this relates to risk factors, access to treatment and treatment outcomes and the broader social consequences of the onset of visual impairment. In doing this, the intention is to inform the development of policy options by identifying those at risk of onset of visual impairment, those factors that minimise this risk, including the role of treatment (cataract surgery), and the impact of visual impairment on other outcomes.

The research made use of data provided by the English Longitudinal Study of Ageing (ELSA), a large multidisciplinary panel survey of a representative sample of people aged 50 and older in England (Steptoe *et al*. 2013). This allowed us to document and analyse changes in visual acuity over time (covering an eight year period) for the same individuals. It also draws upon analysis of The Irish Longitudinal Study of Ageing (TILDA) (Barratt *et al*. 2012) to examine the implications of using standard self-report survey measures of visual acuity, rather than objective assessments.

The research builds on earlier research conducted for Thomas Pocklington Trust that identified the range of social, economic and health inequalities faced by older people with visual impairments (Gjonça and Nazroo 2005, Nazroo and Zimdars 2010, Zimdars *et al*. 2012).

2. Background

Within the UK, around 370,000 people are registered as blind or partially sighted (RNIB 2012). However, registration rates greatly under-estimate the true number of people with a visual impairment, it is thought that the number of people in the UK with sight loss that has a significant impact on daily life is as high as two million (Keil 2008, Winyard and McLaughlan 2009). Deterioration in vision is associated with ageing (Sussman-Skalka, Stuen, and Cimarolli, 2003), with the average rate of deterioration in vision increasing as age increases (Haegerstrom-Portnoy *et al*. 1999, Mojon-Azzi *et al*. 2008). This is in part because some changes to the eye affecting vision are more common in ageing adults, for example losing the ability to focus, declining sensitivity, and needing more light. There are also a number of age-related eye conditions that can lead to severe visual impairment, including macular degeneration, glaucoma, cataracts and diabetic retinopathy (Sussman-Skalka *et al*. 2003). Some eye conditions are treatable and medical intervention can slow deterioration, improve, or restore vision. Cataract surgery for example is often followed by significant improvement in vision (Lundqvist and Mönestam, 2006). Nevertheless, there is a higher proportion of those with untreatable eye conditions in older age groups (Charles, 2007). For example, just considering those registered with a visual impairment shows that within England two thirds (65 per cent) are aged 75 or older and a further 10 per cent are in the 65-74 age range (calculated from: NHS 2011, p. 9-10).

The ageing of the UK population points to the significance of age-related visual impairment for social and health policy, and raises the possibility that the prevalence of visual impairment will rise as the population ages

(RNIB 2010), with some estimating that prevalence will more than double by 2050 (Winyard and McLaughlan 2009). Maintaining and restoring good vision is likely to be critical in retaining independence and wellbeing in later life. Visual impairment is strongly associated with reduced quality of life and depression (Bookwala and Lawson 2011, Evans and Rowlands 2004), although the mechanisms through which this occurs may not be direct (Bookwala and Lawson 2011, Zimdars *et al*. 2012). Vision loss has significant implications for participation in daily activities (Alma *et al*. 2010, Branch *et al*. 1989, Desrosiers *et al*. 2009, Lamoureux *et al*. 2004, Ragland *et al*. 2004, Brennan *et al*. 2005, Zimdars *et al*. 2012). However, research on risk factors for the development of visual impairment, and the social and personal significance of age-related visual impairment, necessary to inform policy, is limited.

A starting point is to investigate the prevalence of visual impairments among older people and the social, economic and health circumstances of those with visual impairments. Cross-sectional analysis of ELSA has been used to estimate the prevalence of visual impairments among the population aged 50 and older (Gjonça and Nazroo 2006). As many as 16 per cent of the population described their vision as less than good, with 1 in 25 reporting poor or worse vision (Gjonça and Nazroo 2006). Visual impairment was more prevalent among women than men and its prevalence increased with age. Building on existing work (Baker and Winyard 1998, Bath 1994, RNIB 2000 and Winyard 1997), the wide range of data collected in ELSA was also used to explore the circumstances of older people with visual impairments, demonstrating high levels of co-morbidity, poverty, social exclusion, disability and low quality of life (Gjonça and Nazroo 2006, Nazroo and Zimdars 2010, Zimdars et al. 2012).

While such work indicates a significant level of need, and a need that policy development should focus on, such cross-sectional associations tell us only a little about the causal processes that lead to visual impairment, the adverse outcomes associated with visual impairment and the factors that relate to improvement in vision. In particular, it is impossible to confidently identify whether the association between visual impairment and poorer social and economic circumstances is a consequence of visual impairment leading to a decline in circumstances, or poorer circumstances increasing risk of onset of visual impairment, or a combination of both. Such causal questions can be more confidently addressed through careful use of longitudinal data to examine the trajectories of a representative sample of the population. Such data allow for an examination of changes in levels of visual acuity, factors associated with deterioration and improvements, outcomes post change, and, importantly, help with the separation of causal processes from associations.

To do this, in this report we use data from the English Longitudinal Study of Ageing (ELSA) to explore the development of visual impairment, the impact of onset of visual impairment, and access to and the consequences of treatment. In particular we ask the following questions in relation to the population aged 50 and older:

1. Are those in poorer socioeconomic positions and/or with existing health conditions more likely to experience deterioration in their vision?

2. Does deterioration in vision lead to worsening social and economic position, decreased wellbeing, and weakening of social connections?
3. Are there inequalities in the uptake of treatment (cataract surgery), and does treatment lead to improvements in vision and, consequently, better circumstances and increased levels of wellbeing?

3. Methods

3.1 Sample

The research presented here is based on secondary analysis of the English Longitudinal Study of Ageing (ELSA), a study that is representative of the population of England, multidisciplinary in focus and longitudinal in nature. This allows for analyses to take account of the complexity of people's lives and of causal processes. In addition, data from the Irish Longitudinal Study of Ageing (TILDA) (Barrett *et al*. 2011) are used to examine the validity of conclusions drawn from analysis of self-reported visual acuity. TILDA contains both self-reported measures of visual acuity that are identical to those contained within ELSA and objective measures of visual acuity.

ELSA (**www.elsa-project.ac.uk**, Steptoe *et al*. 2013) is a panel study containing repeated observations of sample members since it began in 2002. It collects detailed information on the health, economic and social circumstances of a representative sample in England aged 50 and over. The ELSA sample was drawn from respondents to the Health Survey for England (HSE), which uses a probability sampling design with a response rate of around 80 per cent. Respondents are interviewed every two years and, at Wave 3, respondents also participated in a life-history interview that used robust methods to collect information from childhood onwards. Data from the first five waves of ELSA were used in the majority of this analysis, spanning the period 2002/3 to 2010/11, so covering eight years. For the work examining the consequences of change in visual acuity, wave 6 of ELSA (conducted in 2012/13) was also used. Longitudinal studies invariably need to take account of missing follow-up data as a result of non-response. To correct for non-response at both HSE and ELSA interviews, a sample weighting scheme based on the inverse probability of response has been developed. This is calculated by using the detailed information collected within the study to model the likelihood of not responding to an interview. This sample weighting can be used to increase both the cross-sectional and longitudinal representativeness of the sample and is used here to increase the generalisability and validity of the findings.

3.2 Data

The ELSA questionnaire takes 70 minutes on average to administer. Most questions have been drawn from, and been validated in, other studies. Full details of the questionnaire can be found online (**www.elsa-project.ac.uk**). The multidisciplinary focus of data collection in ELSA gives coverage of: physical health, including cardiovascular diseases and chronic conditions (diagnosed and symptoms), pain, age-related symptoms, and subjective health reports; physical and cognitive functioning (both self-report and direct measures of performance); care received, aids, and modifications to housing in relation to disability; mental health; a range of wellbeing measures (life satisfaction, quality of life, positive wellbeing); economics (detailed coverage of income, financial assets, pensions and housing); social networks and social, civic and cultural participation. All of the measures were developed by expert groups and represent ‘cutting-edge’ design leading to high quality data with coverage that has both depth within topic and breadth across topics.

3.2.1 Assessment of vision

Visual acuity is assessed at each wave of ELSA using a number of self report measures that cover overall eyesight and near- and far-sight on a five point scale whereby respondents self-classify themselves as having either excellent, very good, good, fair, or poor vision (with an additional category of registered blind for the overall question). In addition there are questions covering diagnosed eye conditions and treatment for cataracts. The questions used are shown in Box 1.

The measures of visual acuity in ELSA can be considered to be limited by their reliance on self-report. The use of a self-reported measure of visual acuity, rather than an objective measure, is possibly less than ideal for some of the work conducted here, because responses reflect more than objective visual acuity. For example, visual impairment might be perceived to be associated with a high level of dependency, a stigma that perhaps older people might want to resist with a resulting under-reporting of visual impairment (Duckett and Pratt 2001). Alternatively, it might reflect everyday lived experiences rather than the setting within which a visual acuity test is undertaken. As such, self-reported eyesight may be reflective of respondents’ confidence in undertaking tasks, as well their perception of themselves as visually impaired, and with the ability to cope with any visual impairment also likely to inform responses to these questions.

Box 1:ELSA questions on visual acuity and eye conditions

Is your eyesight (using glasses or corrective lens as usual) ... READ OUT…
1 excellent,
2 very good,
3 good,
4 fair,
5 or, poor?
6 SPONTANEOUS registered or legally blind

IF not registered or legally blind:
How good is your eyesight for seeing things at a distance, like recognising a friend across the street (using glasses or corrective lens | as usual)? Would you say it is ...
1 excellent,
2 very good,
3 good,
4 fair,
5 or, poor?

IF not registered or legally blind:
How good is your eyesight for seeing things up close, like reading ordinary newspaper print (using glasses or corrective lens as usual)? Would you say it is ...
1 excellent,
2 very good,
3 good,
4 fair,
5 or, poor?

Has a doctor or optician ever told you that you have (or have had) ... (RECORD ALL)
1. Glaucoma or suspected glaucoma?
2 diabetic eye disease?
3 macular degeneration?
4 cataracts?

IF has ever been told has cataracts:
Have you ever had cataract surgery?
1 Yes
2 No

Given the range of influences on such subjective assessments, it is prudent to assess how measures of self-reported eyesight relate to directly measured visual acuity. Earlier work has explored the validity of self report measures to some extent, with the results providing some reassurance. Analysis of data from two existing studies that contain both self-reported and clinically assessed eyesight, the UK MRC Trial of the Assessment and Management of Older People in the Community (Fletcher *et al*. 2002) and the US Aging, Demographics, and Memory Study (ADAMS; Health and Retirement Study 2001) demonstrated a significant, but not perfect, association between measured and self-reported eyesight – almost all of those objectively classified as having visual impairment were correctly identified with the self-report measure, however a significant proportion of those identified with a visual impairment using the self-report measure were found to have reasonable visual acuity with the objective measure (Nazroo and Zimdars 2010, Zimdars *et al*. 2012). Although these findings suggest that the self-report measure has reasonable validity, as part of the research conducted here we carried out additional work to examine the validity of the self-report measures and, particularly, the conclusions we draw from analysis of self-report data (Whillans and Nazroo 2014).

To do this validation work we used data from The Irish Longitudinal Study on Ageing (TILDA) (Barrett *et al*. 2011). TILDA is a large-scale, nationally representative study of people aged 50 and over living in the Republic of Ireland. TILDA was designed to maximise comparability with other well-established international longitudinal studies, including ELSA. The study provides contemporaneous and directly comparable, self-reported and objective measures of visual function. For the self-report measure of overall vision, respondents were asked questions identical to those used in ELSA (see Box 1). For the objective measure each participant was also invited to undergo a health assessment in a clinical centre that included the assessment of visual acuity using the logMAR chart (Minimal Angle of Resolution), the preferred instrument within a research setting (Grosvenor and Grosvenor 2007). The logMAR chart displays five letters per line, with regular spacing between lines and letters, uniform progression in letter size, and a fine grading scale allowing for greater accuracy and improved test-retest reliability (Bailey and Lovie-Kitchin 2013). Respondents were allowed to wear corrective glasses or lenses for this test, therefore measurements are comparable with self-report measures of vision and reflect corrected visual acuity.

This analysis of these data estimated the probability of self-reported and objectively measured visual impairment in relation to socioeconomic variables and health conditions and behaviours; then it examined the accuracy of self-report measures in identifying measured visual impairment using diagnostic test statistics; and, finally, it analysed the effect of socioeconomic and health variables on (mis)reporting (that is, true positives, true negatives, false positives, and false negatives). Multinomial logistic regression was used to identify social patterning in discrepancies between measures. While objective measures are not entirely free from measurement error (for example, incorrect testing procedure, inaccurate equipment, or scoring), it is unlikely that errors will be correlated with socio-demographic characteristics, therefore discrepancies between subjective and objective measures may be attributable to socio-demographic variations in self-reported vision.

Findings from this work (Whillans and Nazroo 2014) show that subjective and objective indicators of visual impairment were significantly related and that perceived vision is a significant predictor of objective low visual acuity in older people, independent of socioeconomic and health variables. Almost all of those classified as normal vision according to objective visual acuity measures were correctly identified by the self-report measure – 9 in 10 people with normal objectively assessed visual acuity correctly self-reported normal vision; and almost all of those who self-reported normal vision were found to have normal visual acuity when objectively assessed. Good vision is therefore well measured by the self-reported response. Visual impairment is slightly over identified by the self reported assessment, however. Almost 1 in 10 people with normal objectively assessed visual acuity self-reported visual impairment, while three out of four of those who self-reported visual impairment were found to have normal visual acuity when objectively assessed. This over inclusion of those with good measured visual acuity in a poor vision category using a self-reported measure of visual function may result in statistical models developed to predict self-reported visual impairment having lower precision and underestimating the size of effects.

However, objective testing of visual acuity may be an oversimplification of older adults' visual function in daily life, because, to ensure reliability, they rely on high contrast letter recognition under optimal lighting conditions. Many older people with normal acuity are effectively visually impaired in performing everyday tasks under non-ideal conditions involving low and changing light levels, glare, and low contrast. Therefore objective measures of visual acuity may be insufficient for detecting visual impairment as lived (Brabyn *et al*. 2001, Haegerstrom-Portnoy *et al*. 1999). Rather than the over inclusion of poor vision being the result of inaccurate self-reporting, then, the subjective measure may be a more accurate assessment of visual functioning, perhaps representing a cognitive averaging of visual function under the different conditions encountered on a daily basis. In this sense it may be that these two measures should be considered complementary, rather than as capturing the same construct.

We conclude from this validation work (Whillans and Nazroo 2014), therefore, that self-reported vision is a valuable measure of good vision in older people and that the over-identification of visual impairment using a self-report measure may indicate visual impairment beyond that measured by objective tests of visual acuity alone. In this respect, a self-report measure, which is likely to reflect vision under the non-optimal viewing conditions encountered in daily life, may be a more accurate assessment of visual functioning. Given the simplicity of the self-report measure to administer and the correspondence between this and an objective measure of visual acuity, we consequently consider it to be a suitable indicator of visual impairment in older people.

3.2.2 Assessment of social position

Social position was assessed using a measure of economic circumstances (wealth) and subjective social status. Wealth was net total non-pension wealth measured at the benefit unit (household) level, which includes the value of the primary house minus the outstanding primary house mortgage, the value of savings and shares minus debts, and the value of other properties and businesses. Level of wealth was coded into quintiles whereby each wealth category contained one fifth of the population.

Subjective social status was measured using a scale represented by a 10-rung ladder; respondents are asked to identify their social standing in society (somewhere between best off and worst off) and to mark a cross on the rung on which they feel they stand. Subjective social status is argued to capture more subtle differences in status hierarchy than objective economic measures; it reflects the cognitive averaging of standard markers of socioeconomic situation and surmises not only current circumstances, but also epitomises the past, and reflects future prospects (Sing-Manoux *et al*. 2003). Subjective social status was also coded into quintiles.

3.2.3 Assessment of other covariates

Demographic variables included in the models were age (usually grouped in 5-year bands so that non-linear effects could be examined), ethnicity and gender. Some of the models included the effects of medical factors, using measures of diagnoses at baseline of diabetes and hypertension and of smoking. Other measures were only included in specific models and are discussed as they are presented.

4. Results

4.1 Onset of visual impairment

Cross-sectional analyses indicate that the prevalence of visual impairment is socially patterned (Ulldemolins *et al*. 2012, Zimdars *et al*. 2012). In a review of research on social determinants of visual impairment and blindness in the general population, Ulldemolins *et al*. (2012) report that socioeconomic status (measured as non-manual occupational social class, higher income, or higher educational status) was consistently inversely associated with prevalence of visual impairment or blindness. However, there is a dominance of cross-sectional analyses of associations between risk factors and the prevalence of a visual impairment. As described earlier, causal mechanisms underpinning visual impairment can be more convincingly identified using longitudinal data. So, here we used longitudinal data to assess how the risk of onset of visual impairment in the older population in England varies by wealth and subjective social status, having controlled for the effects of a number of other social, behavioural, and medical factors.

4.1.1 Approach to statistical modelling

The ELSA self-report measure of vision was used to identify transitions into visual impairment in the analysis, dichotomising response in two ways: (1) at least moderate vision loss was defined as reporting fair vision or poor vision or blindness and (2) while severe vision loss was defined as reporting poor vision or blindness. Analyses were repeated using both measures.

To do this two samples were created, corresponding with the two measures of visual impairment. For the first, of the initial 11,391 core respondents to ELSA, respondents were excluded if in wave 1 there was non-response to the question on self-reported vision (N=7) or if they had already reported at least moderate vision loss (fair vision or worse), that is if the event being examined had already occurred (N=1865). It was also necessary for participation in wave 2 of the study to have occurred, so that there were longitudinal data on the respondent, which excluded a further 2036 respondents. In drawing the second sample, respondents were excluded if in wave 1 there was non-response to the question on self-reported vision (N=7), if they reported already having severe vision loss in wave 1 (poor vision or blindness) (N=472), and if there was non-response at wave 2 (N=2425). The final analytical samples comprised of 7483 respondents for the analysis of moderate vision loss and 8487 respondents for the analysis of severe vision loss.

Survival analysis techniques were used to identify factors associated with onset of visual impairment. First, life tables were calculated using Kaplan-Meier estimates to describe the distribution of event occurrence over time. All respondents were considered at risk of loss of vision until the occurrence of a visual impairment observation, a censoring event, or the final wave of observation. Kaplan-Meier survival curves were examined to make univariate comparisons of discrete groups of respondents. Cox regression-based tests were then performed as a statistical evaluation for the equality of survival curves and as an indicator of the suitability of each variable for inclusion in subsequent models; predictors were considered for inclusion if the test had a p-value of 0.2 or less. This univariate analysis was supplemented by basic descriptive statistics to examine the distribution of the outcome variables among all respondents.

Second, Cox proportional hazards models were used to analyse the effects of social position (wealth and subjective social status) on the risk of onset of visual impairment, while controlling for the effects of a number of other potentially significant risk factors. Starting with a null model, predictors were entered incrementally into the model; nested models were compared using likelihood ratio tests to assess to overall contribution of the newly entered set of variables. The final models included age at baseline (grouped in five-year bands), wealth (quintile), subjective social status (quintile), health behaviours (smoking), and medical diagnoses (diabetes and hypertension).

4.1.2 Findings

During the 8-year follow up period, of the 7483 respondents in the first sample, a total of 1600 reported the onset of moderate vision loss, 3559 did not experience moderate vision loss during the study, and 2324 respondents left the study without first having reported moderate vision loss. Likewise, of 8487 respondents in the second sample, 501 respondents reported the onset of poor vision or blindness, 4870 did not experience severe vision loss (poor vision or blindness) during the study period, and 3116 left the study without having first reported severe vision loss. Of the 1600 reporting moderate vision loss, around two thirds did not have a diagnosed eye condition (N=1063, 66.8%), while a little under half of all respondents reporting severe vision loss had no diagnosed eye condition (N=231, 46.8%). Cataract was the most common diagnosis in respondents reporting onset of visual impairment and an eye condition.

Descriptive analyses show that with increasing age the risk of visual impairment increases incrementally at younger ages and more rapidly into older age bands. Furthermore, the onset of visual impairment was associated with both wealth and subjective social status. In the analysis of both moderate and severe vision loss, respondents in the lower wealth quintiles were the most likely to report the onset of visual impairment. The poorest wealth quintile was twice as likely to report the onset of moderate vision loss compared with the wealthiest quintile (32.3% compared with 16.0%). When examining severe vision loss, the poorest quintile was almost three times more likely to report onset compared with the highest wealth quintile (10.4% compared with 3.6%).

Respondents' subjective assessment of their relative social status also appeared to have a strong relationship with the onset of visual impairment, in that those who felt that they were among the worst off were considerably more likely to report onset of moderate and severe visual impairment. Compared with those who consider themselves among the best off in society, those in the lowest subjective social status quintile were 2.4 times as likely to report the onset of moderate vision loss (15.2% and 36.8%) and 2.4 times as likely to report severe vision loss (5.6% and 13.4%).

Descriptive statistics also indicate that the onset of visual impairment is associated with gender (with females more likely to experience onset), smoking, diabetes and hypertension.

Multivariate Cox proportional hazard models were used to estimate associations between variables and onset of visual impairment once other characteristics were controlled for. Table 1, which contains hazard ratios with their 95% confidence intervals for each risk factor, shows that in the multivariate analysis gender was a significant risk factor for the onset of moderate vision loss, while the risk of onset of severe vision loss did not differ significantly by gender. After the age of 65, the risk of onset of moderate vision loss was significantly higher compared with the youngest age band; while for each increase in age band from 60-64 years and upwards, the risk of onset of severe vision loss was significantly higher compared with the youngest age band, more than five times higher for those aged 75-79 and more than nine times higher for those aged 80 or older, compared with those aged 52-54. For both measures of visual impairment, being a smoker increased the risk of onset of visual impairment, compared with those who had never smoked, for both moderate vision loss (almost 50% higher risk) and for severe vision loss (around two-thirds higher risk). The risk of onset of visual impairment did not differ significantly between those who had never smoked and those who had given up smoking. Diabetes and hypertension were both associated with a greater risk of onset of both moderate vision loss and severe vision loss.

The effects of social position on the risk of onset of visual impairment were also evident. The risk of onset of moderate vision loss was significantly higher for those in the lowest two wealth quintiles compared with those in the highest wealth quintile (almost a third higher and more than 50% higher respectively). Subjective social status was also a significant predictor of onset of moderate vision loss, independent of measures of wealth; those in the lowest two subjective social status quintiles had a significantly higher risk of onset of moderate vision loss than those in the highest subjective social status quintile (more than 50% and more than twice as high respectively). Similar findings are shown for the risk of onset of severe vision loss. The risk of onset of severe vision loss was 49% higher for those in the middle wealth quintile, 51% higher for the second lowest wealth quintile, and 79% higher for the poorest wealth quintile, compared with those in the highest wealth quintile. While, independent of measures of wealth, those in the lowest subjective social status quintile had an 80% higher risk of onset compared with the highest subjective social status quintile.

Table 1: Cox proportional hazards models of the onset of moderate and severe vision loss

	Moderate vision loss		Severe vision loss	
	Hazard Ratio	95% confidence intervals	Hazard Ratio	95% confidence intervals
Male	1	.	1	.
Female	1.16**	(1.05 - 1.29)	1.20	(0.99 - 1.45)
Age				
52 – 54	1	.	1	.
55 – 59	0.99	(0.83 - 1.19)	1.37	(0.90 - 2.11)
60 – 64	1.20	(0.998 - 1.45)	1.76**	(1.17 - 2.72)
65 – 69	1.41***	(1.18 - 1.69)	2.13***	(1.42 - 3.21)
70 – 74	1.80***	(1.51 - 2.15)	4.19***	(2.86 - 6.12)
75 – 79	2.33***	(1.93 - 2.80)	5.16***	(3.50 - 7.62)
80 +	3.17***	(2.62 - 3.83)	9.30***	(6.34 - 13.66)
Wealth quintile				
Highest	1	.	1	.
Second	1.05	(0.89 - 1.23)	1.16	(0.82 - 1.64)
Middle	1.17	(0.99 - 1.38)	1.49*	(1.07 - 2.08)
Fourth	1.33**	(1.12 - 1.56)	1.51*	(1.09 - 2.09)
Lowest	1.59***	(1.34 - 1.88)	1.79***	(1.30 - 2.48)
Subjective social status quintile				
Highest	1	.	1	.
Second	1.07	(0.81 - 1.42)	0.65	(0.40 - 1.06)
Middle	1.35*	(1.03 - 1.77)	0.75	(0.47 - 1.20)
Fourth	1.53**	(1.14 - 2.04)	0.95	(0.58 - 1.54)
Lowest	2.09***	(1.49 - 2.93)	1.79*	(1.03 - 3.11)
Smokes				
Never smoked	1	.	1	.
Used to smoke	1.03	(0.92 - 1.15)	0.97	(0.79 - 1.18)
Smokes now	1.48***	(1.29 - 1.70)	1.68***	(1.29 - 2.18)
Diabetes				
No	1	.	1	.
Yes	1.44***	(1.22 - 1.71)	1.44*	(1.07 - 1.95)
Hypertension				
No	1	.	1	.
Yes	1.19***	(1.08 - 1.31)	1.21*	(1.001 - 1.45)

* p<0.05, ** p<0.01, *** p<0.001

4.2 Trajectories of visual impairment and their predictors

Having described factors predicting the discrete effect of onset of visual impairment, it is worth moving on to consider a more holistic examination of how vision does, and does not, change over time. Such an approach allows us to contrast the characteristics of those whose vision is stable over time, with those whose vision declines over time, improves over time, or both declines and improves. Using longitudinal data in this way offers the potential for a more complete understanding of the developmental course, causes, and consequences of changes in vision. The aim of the analysis presented here is to provide empirical evidence on the range of different trajectories of self-reported vision in older people and to identify the socio-demographic factors associated with different vision trajectories, adding to our understanding of social inequalities in changes in vision.

4.2.1 Approach to statistical modelling

The sample used for this analysis was restricted by three criteria. First, the sample was limited to core members who responded to all five waves of ELSA, reducing the sample from 11,391 to 5,262. Second, six respondents were excluded who had not answered the question on self-reported general vision in all five waves. These first two criteria were necessary as the analysis of change was based on a full sequence of data, rather than simply examining differences between just two observations. Finally, respondents aged under 60 at wave 1 were excluded because preliminary analysis indicated that the most notable changes in vision trajectories occurred in the over 60s population. So, the analysis used the sequence of responses of 2,956 respondents, aged 60 and over, who self-reported general vision in 5 successive waves of ELSA. Longitudinal weights were used to deal with survey non-response.

Using the TraMiner and Cluster packages in R, a combination of optimal matching (OM) (a method of sequence analysis) and cluster analysis were used to describe and summarise the sequential self-reported assessments of vision by producing a typology of vision trajectories. Multinomial logistic regression modelling (MNLM) was then used to examine the socio-demographic characteristics associated with different trajectories, with age, gender, ethnicity, wealth, subjective social status, diagnosed eye diseases and having had cataract surgery entered as independent variables.

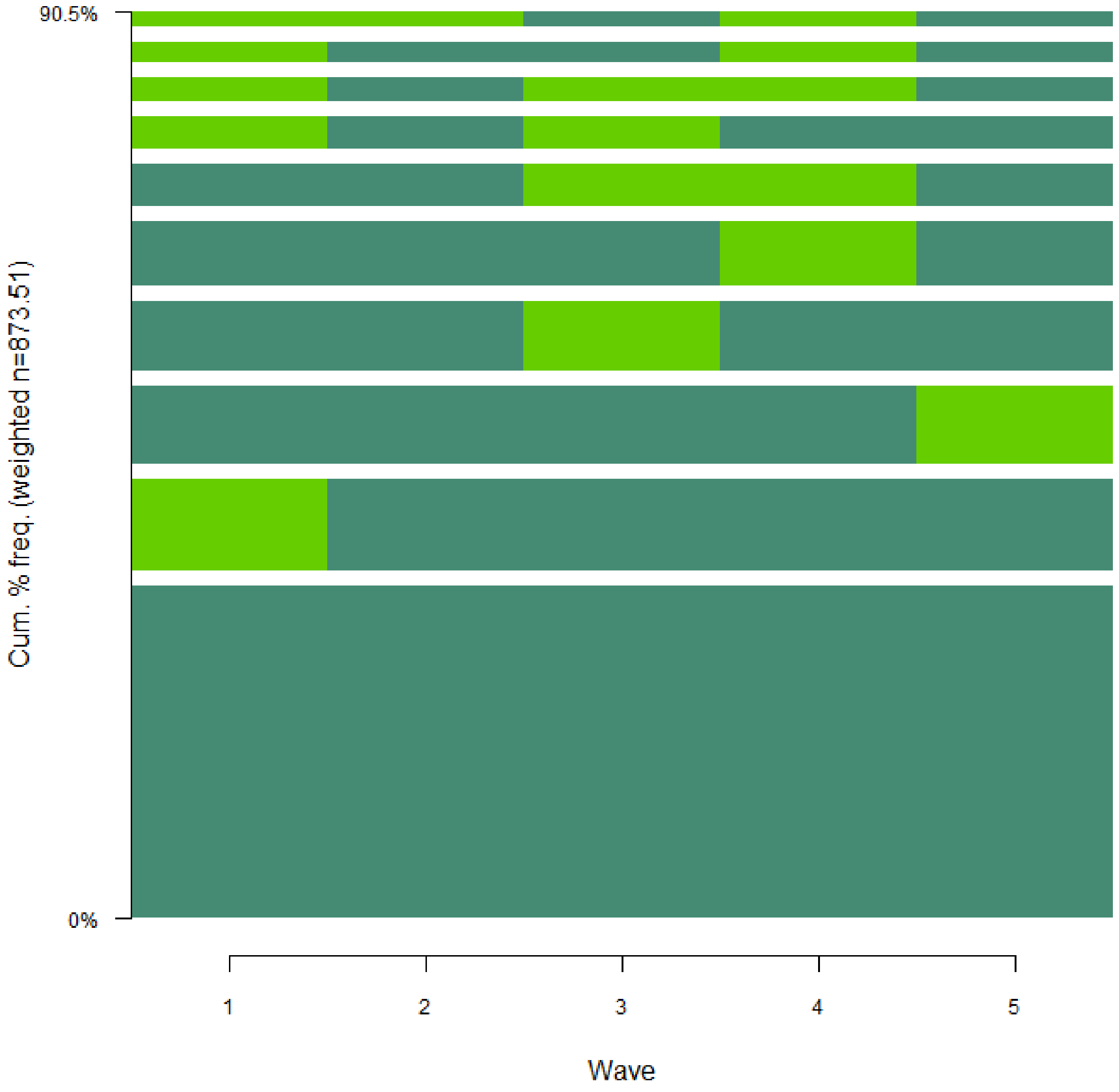
In more detail, optimal matching (OM) is used for identifying patterns in sequence data without making prior assumptions about the kinds of patterns that the data may contain, nor the processes giving rise to variation in trajectories (Abbott and Tsay 2000). All sequences considered here consisted of five observations and each measurement of visual acuity was coded as being one of four states: (1) excellent or very good, (2) good, (3) fair, and (4) poor or blind. In OM, the degree of dissimilarity between individual trajectories is determined by ‘the least number of weighted edit operations that are necessary to turn one sequence into the other (that is, to match the two sequences)’ (Lesnard 2010, pg. 391). Edit operations to match sequences include substitutions of one observed state with another, and insertions and deletions of particular observations. The output from OM is a dissimilarity matrix for each observed sequence, which must then be combined with a data reduction procedure. Agglomerative hierarchical clustering was applied to the resulting OM dissimilarity matrix using the Ward clustering method. This organises the sequences into meaningful groups in a way that maximizes the similarity of cases within each cluster while also maximising the dissimilarity between groups. Deciding how many clusters are necessary to give a faithful representation of the data is a central problem in sequence analysis (Abbott and Tsay 2000, Lesnard 2010). Consequently, two procedures were applied here. Aisenbry and Fasang's (2007) rule of thumb states that the mean within cluster distance should be at least half of the mean between cluster distance to indicate truly distinct groups. Following this, the graphical representations of various cluster solution were examined to ensure that the results were interpretable and meaningful (Abbott and Tsay, 2000).

4.2.2 Findings

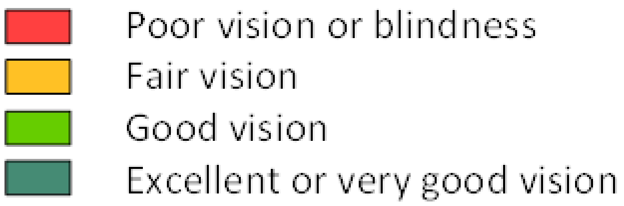
The analysis indicated that an eight-cluster solution best represented the trajectories of visual acuity over the five observations covered by the data. This suggests that there were eight broad types of trajectory experienced by the ELSA responds, Figure 1 illustrates the patterning of these eight trajectories. It plots each of the actual sequences of experience within each trajectory (so eight plots in total). In each plot the sequences are displayed bottom-up in decreasing order of their presence within the trajectory (with proportion of people in the trajectory with that sequence represented by the height of the bar). And, for each plot the level of visual acuity is represented by a colour (dark green is excellent or very good, green is good, orange fair, and red poor or blind). So, for example, in plot 4 the bottom bar is the thickest (so the largest proportion in this trajectory) and is solid red, meaning that poor or blind vision is recorded throughout the study for these respondents. And the next bar up in plot 4, so the second most common sequence in this trajectory, is one that shows a deterioration from fair vision (orange) to poor vision or blindness (red) between waves 1 and 2, with all subsequent waves remaining as poor vision or blindness.

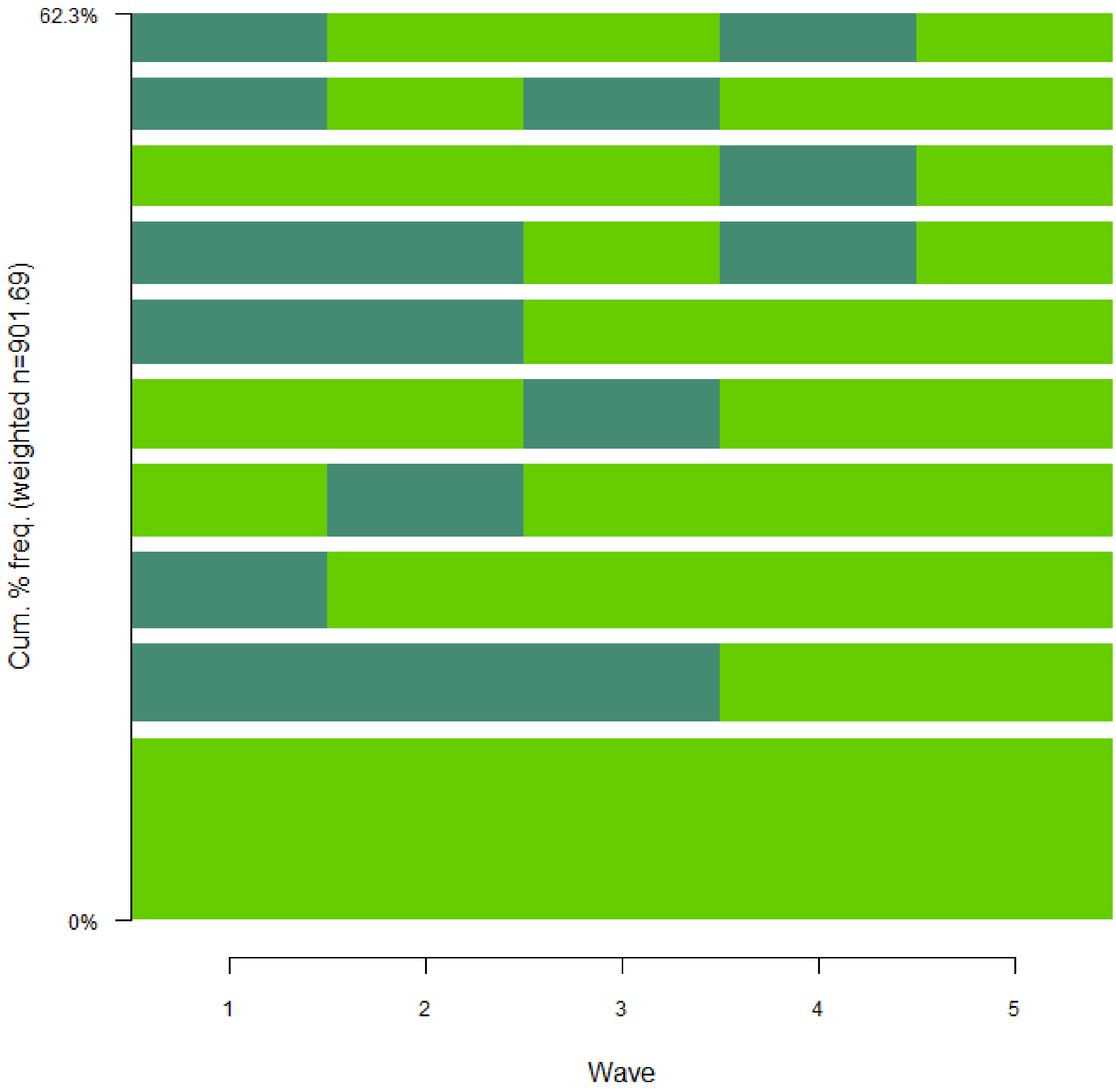
Within the eight-clusters, there are three reflecting stability in reported visual acuity: cluster 1 (stable excellent or very good vision); cluster 2 (stable good vision with some fluctuation); and cluster 3 (stable fair vision with some fluctuation). There are also three clusters reflecting deterioration in vision: cluster 4 (poor vision and deterioration to poor vision); cluster 5 (gradual deterioration from good to fair vision); and cluster 6 (deterioration from excellent to fair vison). The remaining two clusters reflect improvement in reported visual acuity: cluster 7 (improvement from good to excellent vision); and cluster 8 (U-shaped deterioration to fair vision followed by improvement to good vision). Of course there is some variation in experiences within the clusters that is not fully reflected in the brief descriptions provided so far, which is discussed next.

Figure 1: Sequence frequency plots of visual trajectories for an 8-cluster solution

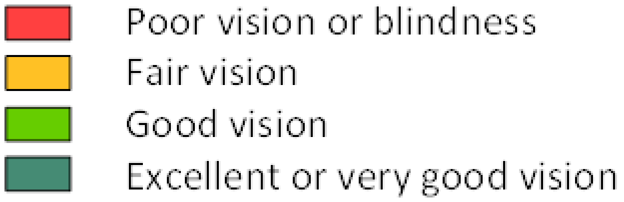


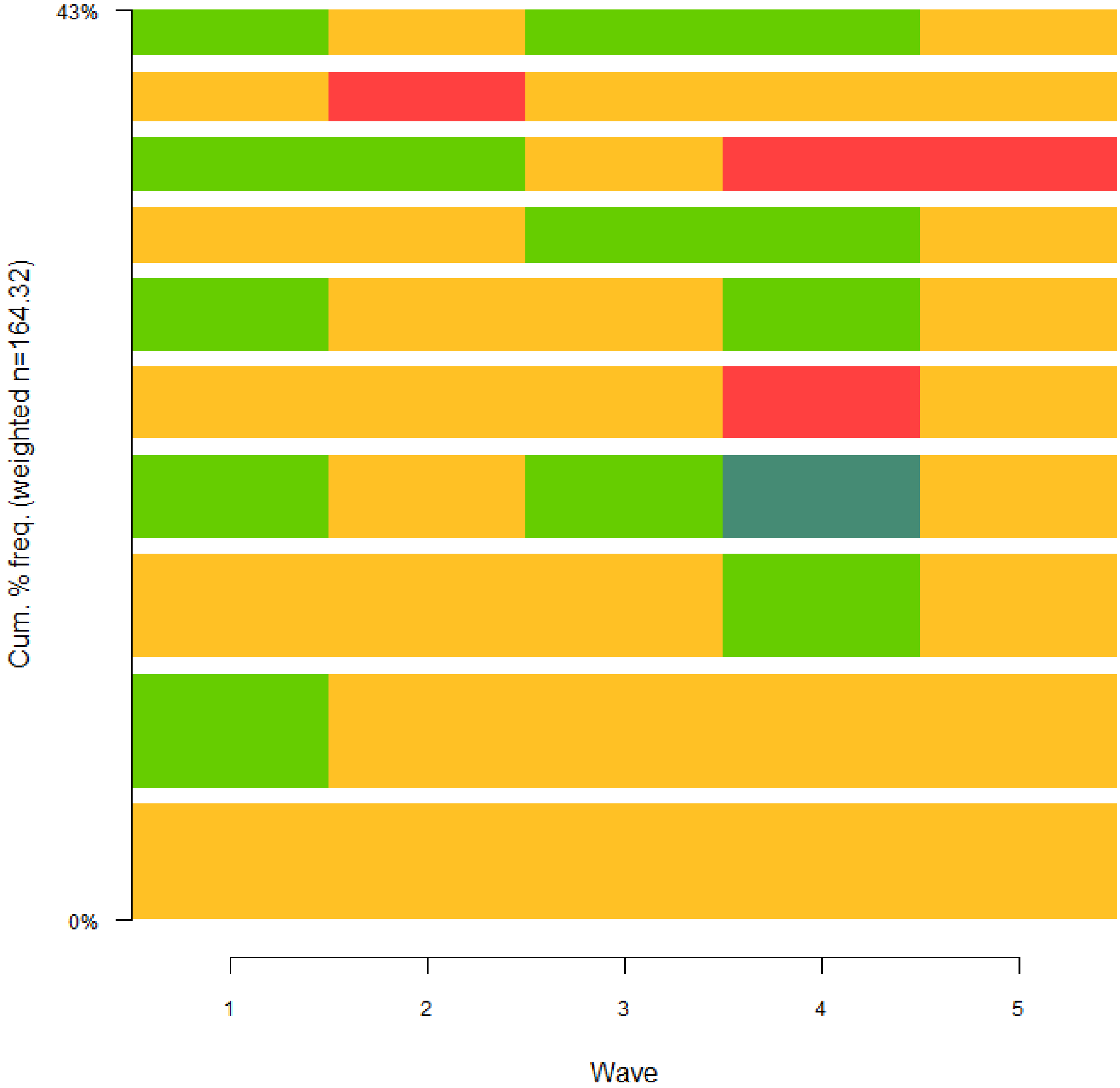
Cluster 1: Stable excellent (and slight fluctuation), N=927, Weighted %=29.7



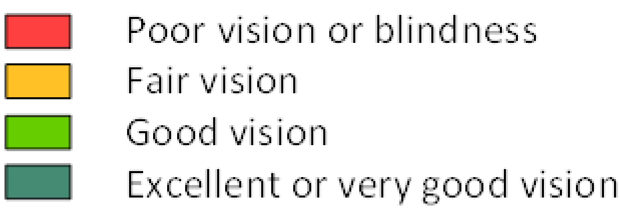


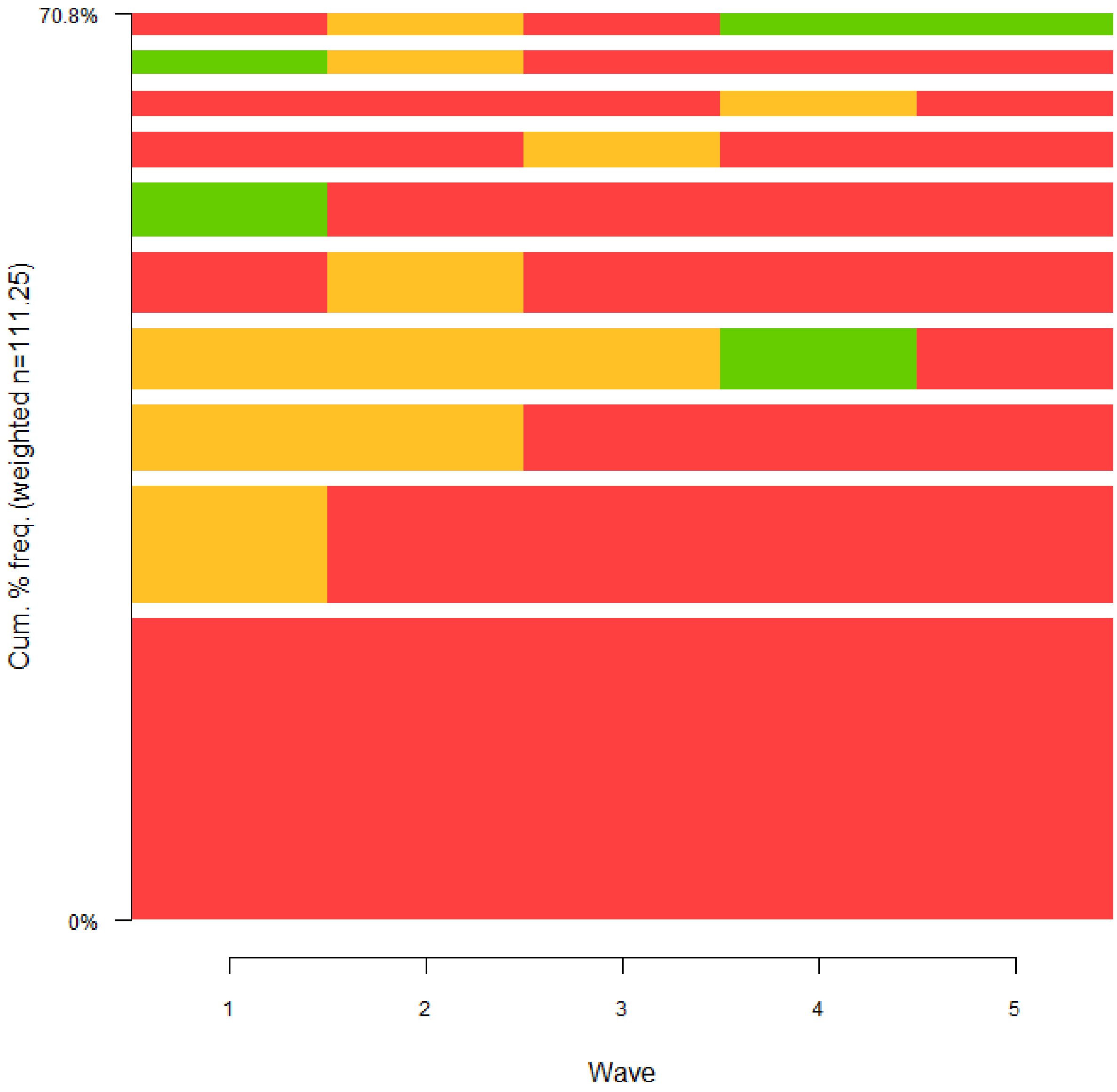
Cluster 2: Stable good vision with some fluctuation, N=905, Weighted %=30.6



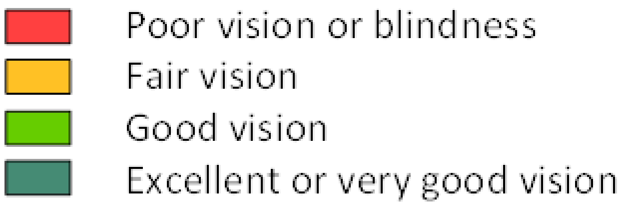


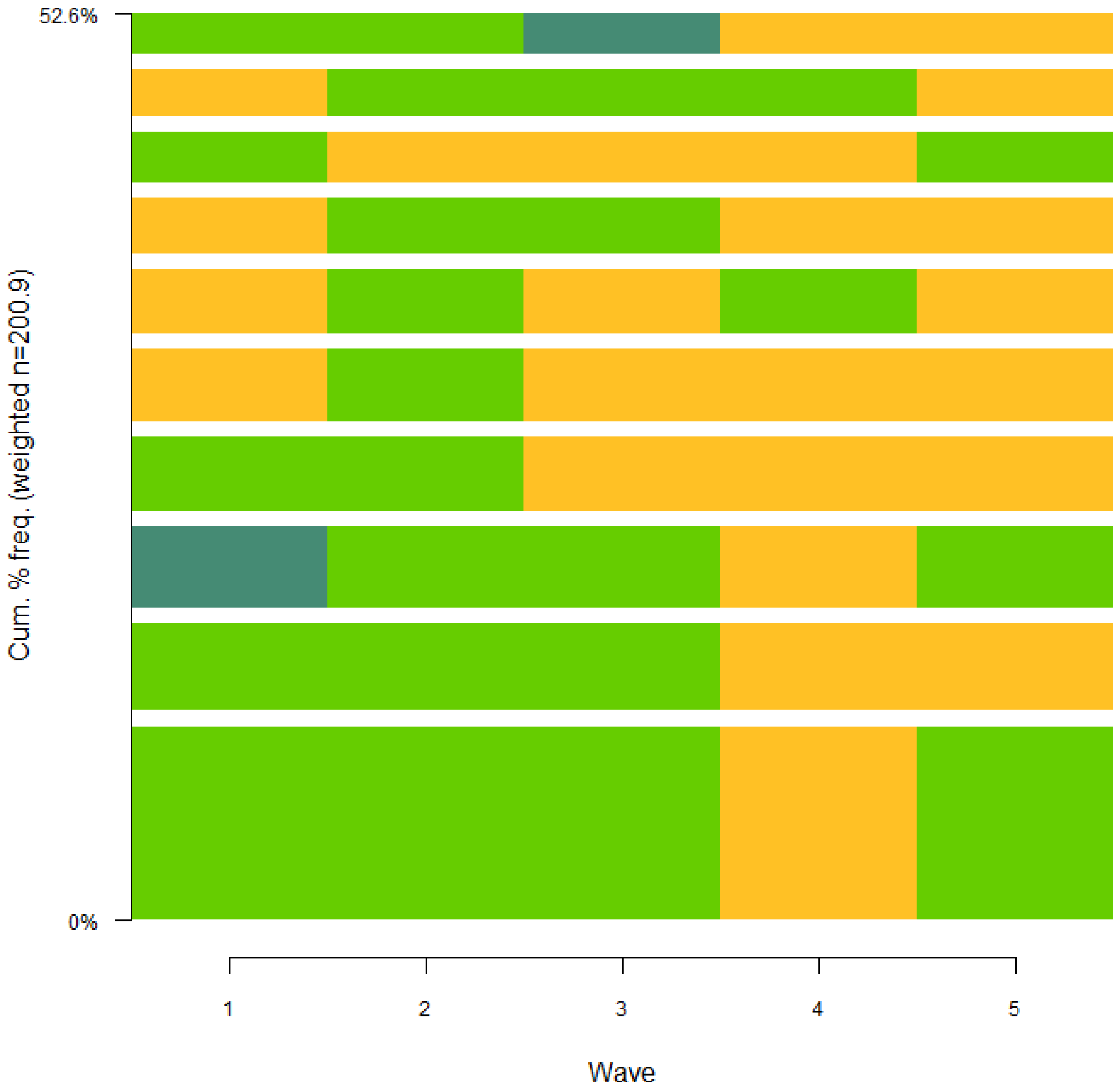
Cluster 3: Stable fair vision with some fluctuation, N=146, Weighted %=5.6



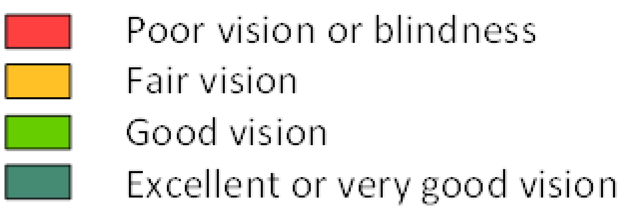


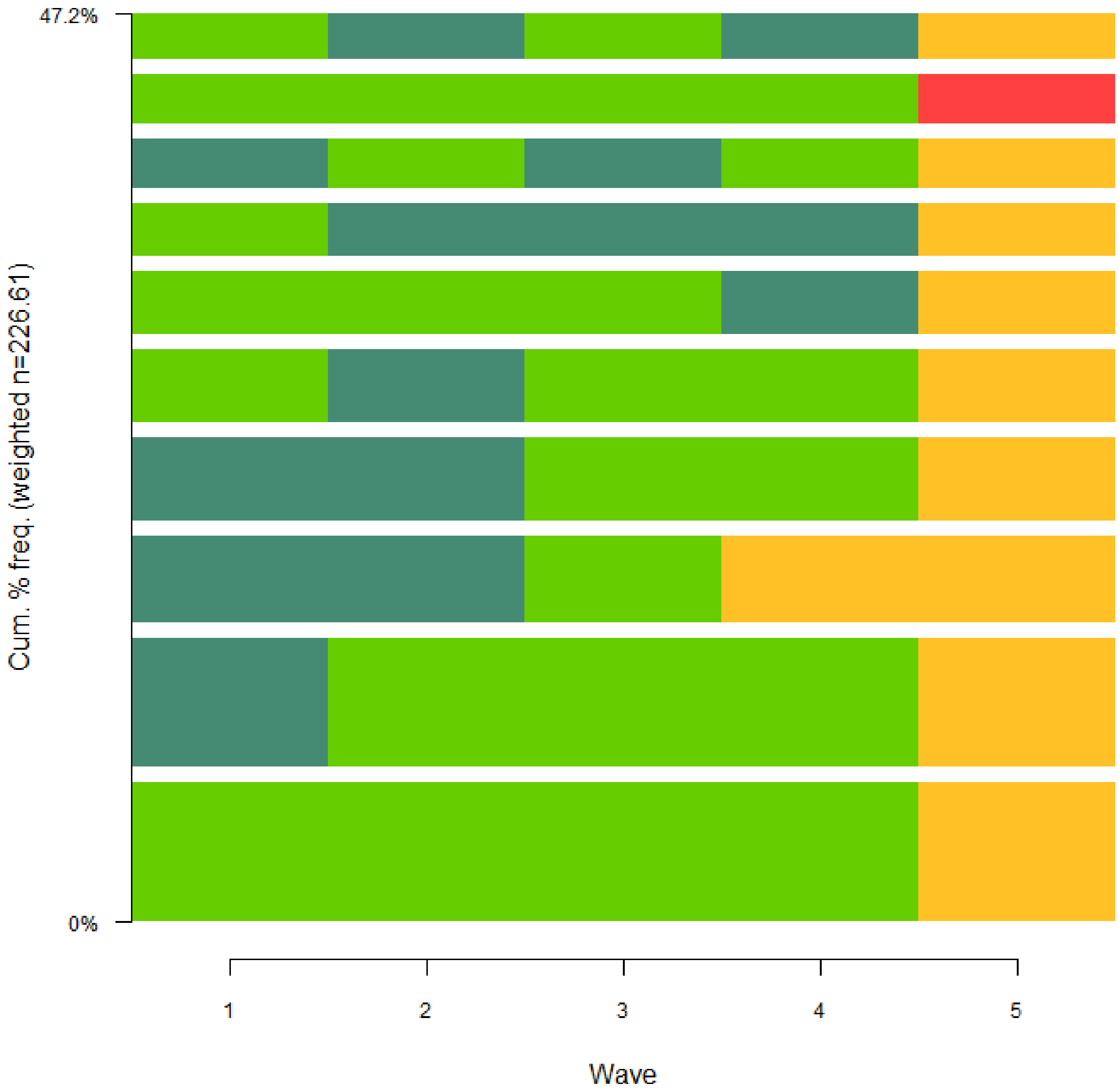
Cluster 4: Poor vision and deterioration to poor vision, N=95, Weighted %=3.8



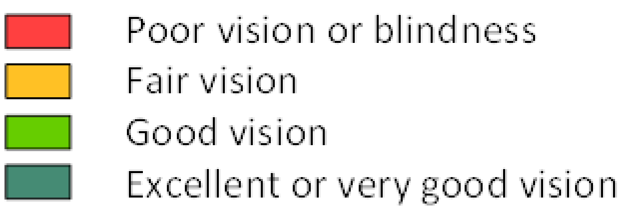


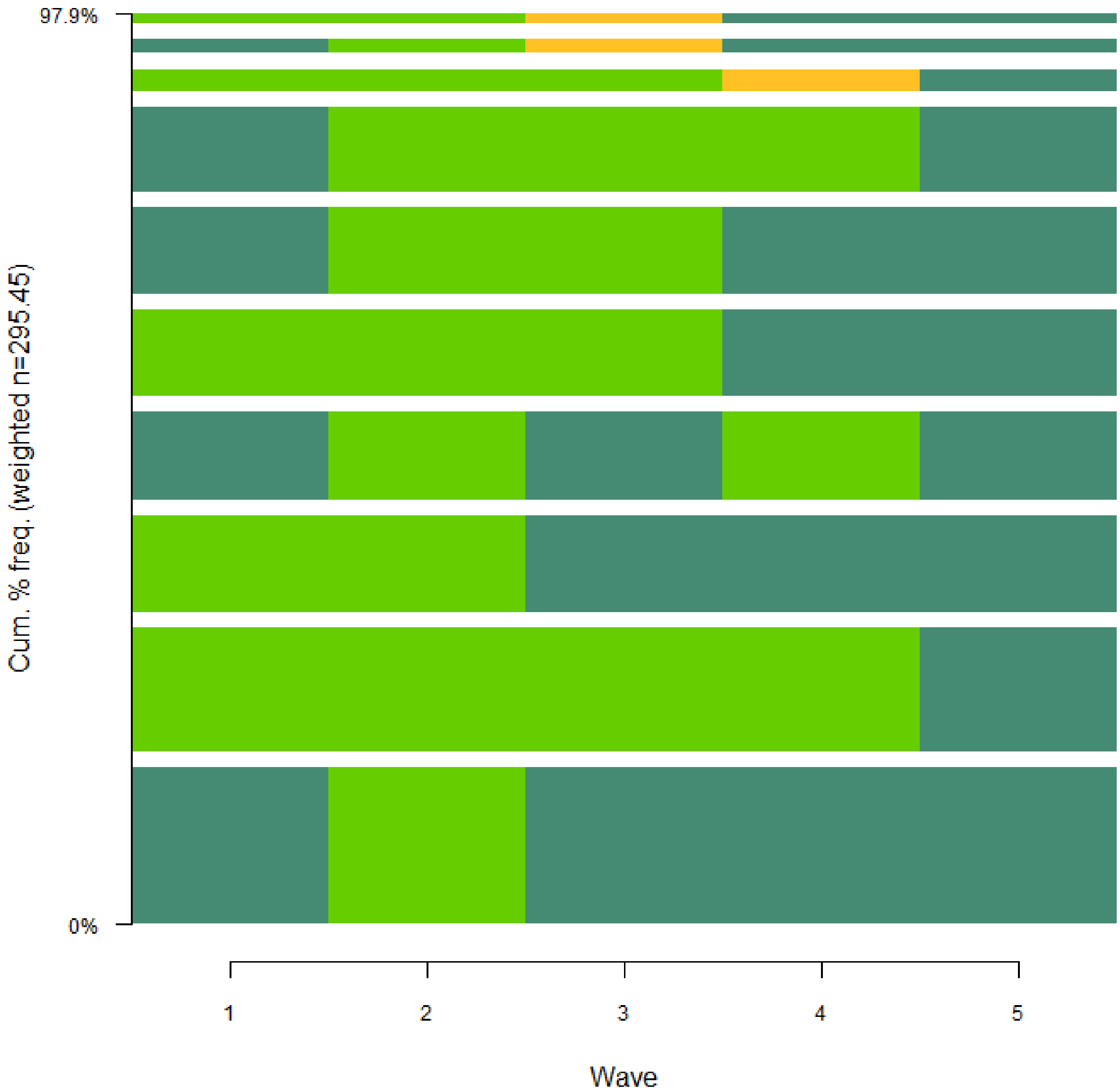
Cluster 5: Gradual deterioration from good to fair vision, N=198, Weighted %=6.8



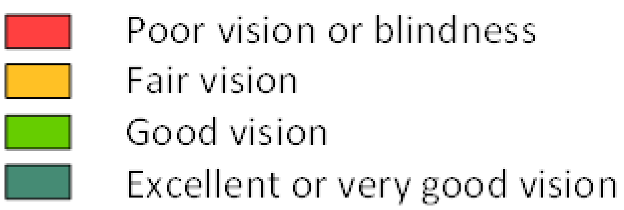


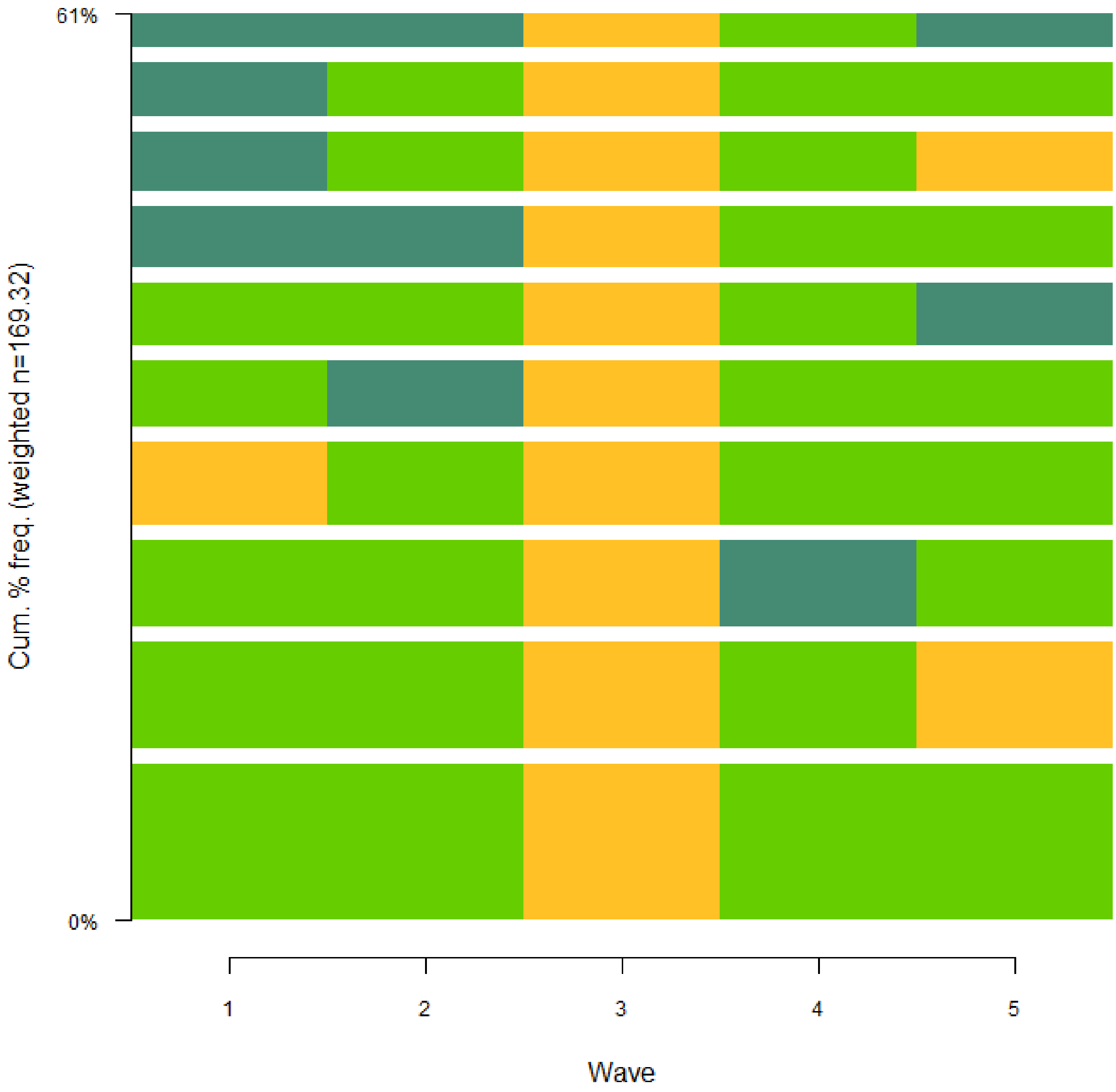
Cluster 6: Deterioration from excellent to fair vision, N=218, Weighted %=7.7





Cluster 7: Improvement from good to excellent vison, N=306, Weighted %=10.0





Cluster 8: U-shaped deterioration to fair vision followed by improvement to good vision, N=161, Weighted %=5.8

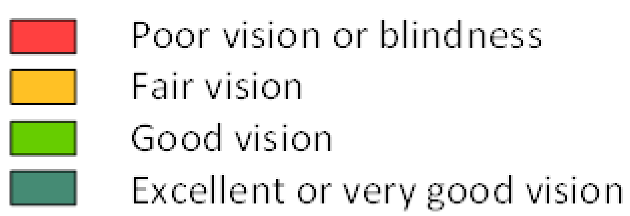


Figure 1 shows that cluster 1, Stable excellent vision (and slight fluctuation around excellent), is the second largest of the eight clusters (29.7% of all sequences analysed). Descriptive statistics indicated that at wave 1, 73.0% of cluster 1 members self-reported excellent or very good vision; by wave 5, this increased to 89.4% reporting excellent or very good vision. 39.0% of cluster 1 members reported stable excellent or very good vision across all 5 waves. Cluster 2, Stable good vision (and slight fluctuation around good), is the largest cluster of the eight-cluster solution (30.6% of all sequences analysed). At wave 1, large proportions of cluster members reported good vision (50.5%) and excellent or very good vision (38.7%). By wave 5, almost all cluster members reported good vision (94.4%). Clusters 1 and 2 together account for just over 60% of all sequences.

Clusters 3 to 8 categorised the remaining 40% of sequences and reflect trajectories containing lower levels of visual function and/or notable change in self-reported vision over time. Cluster 3, Stable fair vision (and deterioration to fair), contains just under 6% of the sample. Within this cluster there were a handful of observations of stable fair vision throughout the period, with the remaining trajectories showing a fluctuation around and deterioration to fair vision. In wave 1, 32.2% of observations from cluster 3 members were self-reported fair vision and 37.9% were good vision; by wave 5, 74.8% of responses were self-reported fair vision. 52.8% of responses across all five waves of ELSA from cluster 3 members were self-reported fair vision.

The three clusters that describe deterioration trajectories contain 18.3% of all sequences analysed. Cluster 4, Poor vision and deterioration to poor, is the smallest but a very distinctive category (3.8%). At wave 1, just over half of the cluster reported poor vision or blindness (51.1%), and over a third reported fair vision (38.0%). By wave 5, 85.0% of the cluster reported poor vision or blindness. Over a quarter of cluster 4 reported poor vision or blindness in all 5 waves (27.7%). Cluster 5 describes trajectories of gradual deterioration from good to fair. The most common response at wave 1 was self-reported good vision (43.9%) and an almost equal proportion reported fair vision (40.5%). By wave 4, 88.3% reported fair vision although by wave 5 many of these had reported an improvement in vision. Cluster 6 contains sequences showing rapid deterioration from excellent to fair vision. At wave 1, two fifths of the cluster reported excellent or very good vision (41.3%) and half reported good vision (49.1%). By wave 5, 65.3% reported fair vision and 34.3% reported poor vision or blindness.

Finally, there were two clusters representing trajectories of improvement. Cluster 7, Improvement good to excellent, accounted for 10.1% of sequences. At wave 1, 44.8% reported good vision and 55.2% reported excellent or very good vision; by wave 5, almost all respondents self-reported excellent or very good vision (99.2%). Cluster 8 reflect a u-shaped trajectory of deterioration to fair then improvement to good. At wave 1, over half of cluster 8 reported good vision (57.1%) and just over a quarter reported excellent or very good vision (26.0%). At wave 3, almost all respondents reported fair vision (98.8%). By wave 5, again over half of cluster members reported good vision (55.3%) and a just over a fifth reported excellent or very good vision (21.6%).

Following the sequence analysis, multinomial logistic regression modelling was used to examine predictors of cluster membership. To ease interpretation, the model was transformed into predicted probabilities (rather than log odds) to readily show how cluster membership was related to the included socio-demographic characteristics (Table 2). The reference group was male, aged 60-64 years at wave 1, in the highest wealth quintile, in the highest subjective social status quintile, and had not had cataract surgery. Negative predicted probabilities reported in Table 2 indicate that members of the group are less likely to report the trajectory type relative to the reference group; a positive predicted probability shows that they are more likely to report the vision trajectory compared with the reference group, all else being held constant.

Compared with men, women were notably more likely to be in cluster 2 and report stable good vision (4.6%), and were less likely to be in cluster 1 and report stable excellent vision (-4.7%), holding all else constant. Age was a significant predictor of cluster membership. As age group increased, individuals were progressively less likely to be part of cluster 1, so, compared with the youngest age group, the oldest were less likely to report stable excellent vision (-12.9%). Increased age was associated with increased probability of membership of cluster 2, reporting stable good vision (the difference between the oldest and youngest group was 2.9%), cluster 4, reporting poor vision (2.4%), and cluster 6, reporting rapid deterioration from excellent to fair (9.1%).

Table 2: Predicted probabilities for membership of visual trajectories

Cluster	1 Excellent	2 Good	3 Fair	4 Poor	5 G to F	6 E to F	7 G to E	8 U shape
Gender								
Female	-0.05	0.05**	0.01	0.001	-0.01	0.02*	-0.01	-0.003
Age (at wave 1)								
65 – 69	-0.02	0.01	-0.02	0.01	0.02	0.02	-0.02	0.005
70 – 74	-0.03	-0.02	0.01	0.01	0.01	0.02	-0.01	0.002
75 – 79	-0.08	0.01	-0.01	0.01	0.01	0.07***	-0.02	0.02*
80+	-0.13	0.03*	0.01	0.02**	0.02*	0.09***	-0.02	-0.03
Wealth								
Second	-0.02	0.01	0.01	0.01	-0.01	0.01	-0.02	0.001
Middle	-0.07	0.02	0.03*	0.03***	0.02*	-0.004	-0.03	-0.005
Fourth	-0.08	-0.04	0.05***	0.03***	0.04**	0.005	-0.01	0.001
Lowest	-0.10	-0.08	0.11***	0.03***	0.04**	0.02*	-0.03	0.01
Subjective Social Status								
Second	-0.09	0.05	0.02	0.002	-0.01	-0.02	0.01	0.03*
Middle	-0.16	0.11***	0.03	0.004	-0.01	-0.02	-0.01	0.06**
Fourth	-0.17	0.05**	0.04*	0.01	0.005	-0.01	-0.03	0.10**
Lowest	-0.22	0.09***	0.07**	0.05**	0.005*	-0.003	-0.08	0.09***
Treatment and Eye Diagnoses								
Cataract Surgery	0.079	-0.07**	-0.003	0.002	0.004	-0.05***	0.03	0.01
Glaucoma	-0.16	0.07***	0.04***	0.01***	0.001*	0.06***	-0.03	0.001**
Diabetic retinopathy	-0.10	0.03	-0.002	0.02**	-0.02	0.07**	0.01	-0.01
AMD	-0.18	-0.07*	0.04***	0.10***	0.07***	0.10***	-0.07	0.01**
Cataracts	-0.16	-0.004***	0.04***	0.01***	0.05***	0.08***	-0.03	0.02***

* p<0.05, ** p<0.01, *** p<0.001

The diagnosis of eye disease and the uptake of cataract surgery were significant predictors of vision trajectory. As would be expected, the diagnosis of an eye disease had a strong negative association with reporting stable excellent vision (cluster 1) and a negative association with reporting improvement in vision from good to excellent (cluster 7); it also had a positive association with reporting fair vision and deterioration to fair vision (cluster 3) and poor vision (cluster 4) and rapid deterioration from excellent to fair vision (cluster 6). Furthermore, respondents reporting age-related macular degeneration were more likely to report gradual deterioration from good to fair vision (cluster 5, 6.7%) and less likely to report stable good vision (cluster 2, -7.4%) and improvement from good to excellent vision (cluster 7, -6.9%); respondents with diagnosed cataracts were also more likely to report gradual deterioration from good to fair vision (cluster 5, 4.8%) and less likely to report improvement from good to excellent vision (cluster 7, -2.8%). Holding all else constant, having undergone cataract surgery was seen to be negatively associated with stable good vision (cluster 2, -7.4%) and rapid deterioration from excellent to fair (cluster 6, -4.9%) but positively associated with reporting stable excellent vision (cluster 1, 7.9%). It must be remembered that these binary variables indicated that the eye disease was diagnosed or that cataract surgery was performed at some point during the 8-year observation window and the timing of any diagnosis or medical intervention is obscured.

Having controlled for the effects of a number of demographic characteristics and medical diagnoses and treatment, social position was significantly related to cluster membership, both in terms of material wealth and subjective social status. Decreasing levels of wealth was associated with decreased probability of more optimal vision trajectories (clusters 1 and 2) and increased probability of suboptimal trajectories (clusters 3, 4 and 5). Compared with the highest wealth quintile, those in the lowest wealth quintile were 10.4% less likely to report stable excellent vision (cluster 1) and 7.6% less likely to report stable good vision (cluster 2), 10.7% more likely to report fair vision and deterioration to fair vision (cluster 3), 3% more like to report stable poor vision (cluster 4) and 4.3% more likely to report a gradual deterioration from good to fair vision (cluster 5).

Subjective social status has a significant effect on cluster membership beyond that already accounted for by material wealth. Decreasing levels of subjective social status was associated with decreasing probability of more optimal vision trajectories (clusters 1 and 7). Compared with the highest subjective social status quintile, those in the lowest subjective social status quintile were 21.7% less likely to report stable excellent vision (cluster 1) and 7.9% less likely to report a slight improvement from good to excellent vision (cluster 7). On the other hand, a decrease in the levels of subjective social status was associated with an increase in the probability of suboptimal trajectories (clusters 3 and 4). Those in the lowest subjective social status quintile compared to the highest subjective social status quintile were more likely to report stable fair vision and deterioration to fair vision (cluster 3, 6.5%) and poor vision and deterioration to poor vision (cluster 4, 4.7%).

4.3 The role of treatment – cataract surgery

Cataracts remain the leading cause of visual impairment among older people worldwide (Asbell *et al*. 2005). Surgical removal of the cataract with intraocular lens implantation remains the only effective treatment available to restore or maintain vision (Asbell *et al*. 2005, The Royal College of Ophthalmologists 2010); this procedure can provide both immediate and lasting improvements in vision unless complicated by the onset of another eye disease (Lundqvist and Mönestam 2006, Brenner *et al*. 1993, Mallah *et al*. 2001, Polack 2008). The uptake of treatment by those who need or are eligible for surgery is argued to be a function of the effectiveness of healthcare delivery services: services that are inaccessible, inappropriate, or unaffordable will not be utilised by (sub)populations, who consequently live with untreated cataracts (Taylor 2000).

In England, cataract surgery is the most common elective surgical procedure (Hospital Episodes Statistics 2010-2011). In primary care a minimum level of vision loss must typically be identified in patients before they will be considered for cataract surgery, but threshold levels and criteria range widely (Coronini-Cronberg *et al*. 2012). This has given rise to the possibility of a 'postcode lottery' in England, whereby the availability of some healthcare services is dictated by geography (Khan *et al*. 2010, Lee *et al*. 2013, Javitt *et al*. 1995). However, Kennan *et al*. (2007) show that the rate of cataract surgery within a local authority area has a positive correlation with the index of multiple deprivation (IMD), such that the greater the deprivation in an area the higher the rate of cataract surgery. This suggests that access to care is not significantly compromised in socially deprived local authorities. However, such a conclusion does not take into account other socioeconomic factors and is based on aggregate data rather than individual markers of need. So, using longitudinal data and survival analysis techniques, here we set out to identify whether socioeconomic factors relate to the uptake of cataract surgery, having controlled for the effects of other relevant factors (gender, ethnicity, age, self-reported vision, medical recommendation for surgery, and private health insurance coverage).

4.3.1 Approach to statistical modelling

In each wave, ELSA respondents were asked, ‘have you ever had cataract surgery?’ In Wave 1, this variable was used to identify those individuals who had already undergone cataract surgery when they entered the study. The data from subsequent waves were then used to identify those who received treatment during the 8-year period covered by this study.

Of the initial sample of 11,391 core respondents, 3,159 respondents either reported having cataracts on entry to the study (N=1,543) or reported a new diagnosis of cataracts in subsequent waves (N=1,616). Of these respondents, those who entered the study having already had cataract surgery were excluded, because the event being examined had already occurred (N=784). It was also necessary for respondents to be observed at both wave 1 and wave 2, which excluded a further 284 respondents. The final sample comprised 2,091 respondents who were diagnosed with cataracts prior to or during the study, had not undergone cataract surgery prior to the first survey observation, and had also provided a response in the first two waves of the study.

Although in England there is a universal free health service from which cataract surgery is available, over 12% of the population is covered by private health insurance schemes (Boyle 2011). In the US, type and level of insurance has been shown to be associated with variations in cataract surgery uptake rates (Javitt *et al*. 1995, Goldzweig *et al*. 1997, Abraham *et al*. 2006, Williams *et al*. 2006). So, we include a variable in the models indicating whether the respondent has private health insurance or not.

A measure of the respondent's self-reported baseline (preoperative) visual function was also included in the model (self-reported excellent, very good, good, fair, poor or blind) as was whether the respondent had received a recommendation for surgery from a medical professional (no recommendation, recommended, recommendation not known).

Survival analysis techniques were used to account for time to surgery. Life tables were calculated using Kaplan-Meier estimates to describe the distribution of cataract surgery uptake over time. Cox regression-based tests were then performed as a statistical evaluation for the equality of survival curves and as an indicator of the suitability of each variable for inclusion in subsequent models. Following this, Cox proportional hazards models were used to analyse the effect of wealth on the uptake of cataract surgery, while controlling for the effects of a number of other potentially significant risk factors. Starting with a null model, predictors were entered incrementally into the model; nested models were then compared using likelihood ratio tests to assess the overall contribution of sets of variables.

4.3.2 Findings

During the 8-year follow up period, of the 2091 respondents included, 740 underwent cataract surgery, 902 did not receive treatment during the study, and 449 respondents left the study without first having reported the uptake of treatment. Descriptive analysis suggested that there was no clear relationship between wealth and the uptake of cataract surgery, although those in the lowest wealth quintile were the most likely to undergo treatment. On the other hand, age, holding private health insurance, self-reported visual acuity, and receiving a recommendation for treatment appeared to be related to the uptake of treatment.

Multivariate Cox proportional hazard models were used to estimate independent associations between wealth and the uptake of cataract surgery, controlling for the effects of other variables. The model showed that gender was not a significant factor in the uptake of cataract surgery, having controlled for the effects of other variables (Table 3). Age was a significant factor in the uptake of cataract surgery and with increasing age the likelihood of undergoing cataract surgery increased. Compared with the youngest age-band, the likelihood of treatment uptake was 48% higher for respondents aged 60-69 years at baseline, 60% higher for people aged 70-79 years, and 75% higher for those aged 80 and over. A gradient in hazard ratio was also seen in the effect of self-reported vision at baseline (preoperative) on the uptake of cataract surgery, with self-reported poor vision or blindness at baseline having a significant effect on the uptake of treatment (an almost 50% higher rate than those with reported excellent or good vision).

Table 3: Cox proportional hazard model for receipt of cataract surgery

		Hazard Ratio	95% confidence intervals	Probability
Gender				
	Male	1	.	.
	Female	0.88	(0.77 - 1.01)	0.063
Age group				
	50-59	1	.	.
	60-69	1.48	(1.16 - 1.89)	0.002
	70-79	1.60	(1.26 - 2.03)	0.000
	80 and over	1.75	(1.34 - 2.28)	0.000
Wealth				
	Highest	1	.	.
	Fourth	0.87	(0.70 - 1.08)	0.206
	Middle	1.05	(0.87 - 1.28)	0.602
	Second	0.86	(0.70 - 1.06)	0.156
	Lowest	1.13	(0.92 - 1.39)	0.236
	Missing	0.48	(0.16 - 1.45)	0.194
Health insurance				
	No private insurance	1	.	.
	Private insurance	1.21	(0.99 - 1.48)	0.061
Self-reported vision				
	Excellent	1	.	.
	Very good	0.92	(0.71 - 1.19)	0.529
	Good	1.01	(0.79 - 1.29)	0.957
	Fair	1.23	(0.93 - 1.62)	0.143
	Poor	1.46	(1.04 - 2.04)	0.028
Treatment Recommended				
	No recommendation	1	.	.
	Recommended	5.49	(4.11 - 7.33)	0.000
	Not known	3.53	(2.64 - 4.73)	0.000

Wealth was not related to likelihood of having cataract surgery, and neither was private insurance coverage (although for the hazard ratio for private insurance coverage was positive (1.2) and on the border of statistical significance (p=0.06), suggesting that there may be an effect). In contrast, reporting receiving a recommendation for cataract surgery by a medical professional increased the likelihood of undergoing treatment by a very large amount, more than five times the rate of those who did not receive such a recommendation even after controlling for other factors.

Following this analysis, a final check on the possible contribution of wealth was assessed by also running a model that included all variables except wealth. Likelihood ratio tests comparing this model nested within the model that included wealth indicated that having controlled for the effects of all other variables, wealth did not make a significant contribution to the overall fit of the model (LR chi^2=10.54, p=0.061), even though it did when included on its own (LR chi^2=164.11, p<0.000).

4.4 Consequence of change in visual acuity

Poor vision is also associated with lower levels of a wide range of outcomes, including physical functioning (Gjonça and Nazroo 2006, Nazroo and Zimdars 2010, Zimdars *et al*. 2012, Ivers *et al*. 1998, West *et al*. 1997), self-rated health (Gjonça and Nazroo 2006, Wang et al. 2000), mental health (Gjonça and Nazroo 2006, Nazroo and Zimdars 2010, Zimdars *et al*. 2012, Bookwala and Lawson 2011; Rovner *et al*. 2002), social engagement (Gjonça and Nazroo 2006, Nazroo and

Zimdars 2010, Zimdars *et al*. 2012, Weih *et al*. 2000), wealth (Gjonça and Nazroo 2006, Nazroo and Zimdars 2010) and an increase in risk of mortality (McCarty et al. 2001). However, much of the evidence demonstrating these associations is drawn from the analysis of cross-sectional data, meaning that casual direction in these associations is proposed, rather than demonstrated. As previous sections of this report have shown, visual acuity follows from social and economic factors. In particular, those in poorer economic positions and with lower subjective social status are at greater risk of onset of visual impairment and of having poor and declining, rather than good, trajectories of visual acuity. This means that the cross-sectional associations between visual acuity and socioeconomic position might be causally driven by socioeconomic position rather than visual acuity, and that the associations between visual acuity and other outcomes might flow from socioeconomic effects rather than from the effects of visual acuity.

To pin down causal effects further, this section of the report examines changes in a range of relevant outcomes that follow change in level of visual acuity. So, even if change in levels of visual acuity are in part driven by socioeconomic factors, this allows us to examine the possibility that change in visual acuity has reciprocal causal effects on social and economic outcomes and wellbeing. There is currently little evidence concerning impacts of visual change among older adults, so examination of the associations between changes in vision and social and wellbeing outcomes has important policy implications.

4.4.1 Approach to statistical modelling

For this analysis we used waves 1 to 6 of ELSA, spanning a ten year period from 2002-2003 to 2012-2013, including those respondents from wave 1 who responded to at least two consecutive waves of ELSA, so that a change in vision over a two-wave period could be assessed. Where respondents have participated in all waves of data, a maximum of five changes in vision are recorded (waves 1-2, 2-3, 3-4, 4-5 and 5-6). Respondents are included in the data at any point at which they have provided sufficient information. For example, a respondent with missing data at waves 3 and 4 will still have their two measured changes in vision recorded in the analysis (so in this instance those would be from the periods of waves 1-2 and 5-6). The final analyses consist of 33,369 observations of vision change over the entire data period taken from a sample of 11,196 individuals.

To assess change in visual acuity the analysis here uses the full range of responses to the question asking for self-reported visual acuity (see Box 1), although those stating they were registered blind were combined with those stating poor vision due to low numbers. Change in self-reported vision corresponds to an individual moving between two of the ordinal categories between consecutive waves. However, rather than considering all changes as conceptually equivalent, the analysis focussed on three types of change that we suggest have different levels of significance to the individual concerned. First are those who see a two-category deterioration or improvement, but remain within an optimal vision range (so moving from the category ‘excellent’ to ‘good’, or ‘good’ to ‘excellent’). Second are those who see at least a two category deterioration or improvement and as a consequence move from within an optimal vision range to a suboptimal vision range, or vice versa (moving from either ‘excellent’ or ‘very good’ to ‘fair’ or ‘good’ to ‘poor’ and vice versa). Third are those who experience a one-category decline or improvement in vision but remain within the suboptimal vision range (moving from ‘fair’ to ‘poor’, or from ‘poor’ to ‘fair’). To examine the impact of these changes we compare them with a reference category comprised of those who see no changes in vision over the two-wave measurement period, or who see an improvement or deterioration of just one ordinal category within the optimal vision range (those moving between excellent and very good, or between very good and good).

The study examines the impact of vision change on change in four outcome measures: symptoms of depression (Center for Epidemiological Studies Depression scale (CES-D)), quality of life (Control, Autonomy, Self-realisation and Pleasure scale (CASP)), social engagement and income. To measure change in outcome, baseline outcome variables (that is, the value before the change in vision) are included in each of the analyses, so coefficients represent the size of change in the outcome of interest.

Depressive symptoms are measured using an eight-point version of the CES-D score (Radloff 1977). The score identifies potential indicators of depression in the week prior to interview, such as feeling depressed, lonely or sad, feeling that everything was an effort and having restless sleep. The scale ranges from 8 (highest number of depressive symptoms) to 0 (no depressive symptoms).

Quality of life is measured using the CASP scale (Hyde et al. 2003). A 15 factor scale is included, rather than the original 19 factor scale

(Vanhoutte and Nazroo 2014), and covers aspects such as feelings of control, pleasure, enjoyment, meaning, sociability, happiness, opportunity and satisfaction. When asked how often certain feelings or thoughts are experienced (for example, ‘I look back on my life with a sense of happiness’), the respondent is asked to rate their response to each question as either ‘often’, ‘sometimes’, ‘not often’ and ‘never’. The scale ranges from 0 (poorest quality of life) to 45 (highest quality of life).

Social engagement is measured using a binary variable describing whether or not the respondent belongs to any organisations, clubs or societies, including political parties, environmental groups, neighbourhood watch groups, religious groups, charitable associations, educational groups or classes, social clubs and exercise classes or gyms.

The final outcome measure is equivalised income. The variable is continuous, and is comprised of an individual’s total income from employment, pensions, benefits, assets and other sources, adjusted to account for household size.

The analyses control for a set of covariates that are relevant to both vision change and the outcomes of interest, gender, age, ethnicity, wealth, subjective social status and self-rated health. The models also adjust for baseline levels of self-reported vision.

Models are run separately for each of the outcomes of interest. Random effects two-level hierarchical models were used to adjust for the clustering of the data within individuals and obtain parameter estimates alongside their standard errors. The first set of models in the final analyses adjust for gender, age and baseline outcome variables, and the second set of models also adjust for baseline vision, ethnicity, wealth, subjective social status and self-rated health.

4.4.2 Findings

Around 90% of the observations of self-reported visual acuity over two waves were stable for both men and women. Around 5% of these observations showed some deterioration in vision over the two-wave measurement period and around 4% of these observations showed an improvement in vision over the two-wave periods.

As would be expected, age showed an association with categories of vision change. The youngest respondents were more likely to experience either stable vision, or changes within the optimal vision categories, while the oldest respondents were more likely to experience a decline from fair to poor vision. Changes in vision were also associated with wealth. Around 35% of people who see a deterioration from fair to poor (within suboptimal) vision belong to the lowest wealth quintile, compared to 8.7% who belong to the wealthiest quintile, and stable vision showed a graded relationship with wealth quintile.

Table 4 shows the results of the multilevel regression analysis of the effects of both deterioration and improvement in vision on the outcomes of interest. Stronger associations appear to exist between deteriorations in vision and outcomes than improvements in vision and outcomes. In the models controlling for just gender, age and baseline outcome, deteriorations of any kind in vision are consistently associated with deterioration in all four outcomes, with the exception of the effect of deterioration within the suboptimal categories on income (although in this case the finding was consistent with deterioration). As we might expect, the largest coefficients for worsening of depression, quality of life and income are observed among those whose vision changes from optimal to suboptimal, while for organisational engagement the largest effect was for deterioration of vision within the suboptimal category. Given that the models are dealing with short term change (over a two year period), the size of these effects appear substantial. For example, for those whose vision changed from optimal to suboptimal, there is:

- For depression symptoms (CES-D) an average rise of 0.6 points from a mean of 2.1 (mean score is not shown in the table), so a 29% rise (standardised to any change for those whose vision remained stable);
- For quality of life score an average drop of 1.8 points from a mean score of 24.6 (mean score is not shown in the table), so a 7% fall (standardised to any change for those whose vision remained stable);
- For low social engagement, a rise of 6% from a rate of 33% (rate is not shown in the table), so an 18% rise in the risk of low social engagement (standardised to any change for those whose vision remained stable); and
- An average drop in income of almost £46 per week from a mean of £245 (mean is not shown in the table), so a 19% fall (standardised to any change for those whose vision remained stable).

Although effects were smaller, improvements in vision were associated with significant improvements in outcomes, especially among those whose vision improves within the optimal categories (good to excellent). Here, respondents see significant reductions in symptoms of depression, and increases in quality of life, social engagement and income. There are also improvements in wellbeing outcomes (depression and quality of life) for those moving from suboptimal to optimal vision.

In the fully controlled models, which adjust for other factors associated with these outcomes, effect sizes are reduced for deterioration in vision, but in many cases remain statistically significant. Deterioration from optimal to suboptimal vision is associated with a significant increase in depression scores and significant declines in quality of life and organisational engagement scores. Deterioration within suboptimal vision categories is associated with a smaller, yet still significant, worsening of depression scores and quality of life scores. For improvements in vision most of these effects decrease and become no-longer statistically significant in the fully adjusted models, although some effects on quality of life and social engagement remain.

Table 4: Effect of changes in vision on change in wellbeing, social engagement and economic outcomes

Regression coefficients and standard errors

	Model 1				Model 2			
	CES-D	CASP	Low Social engagement	Income	CES-D	CASP	Low social engagement	Income
Stable vison (reference)								
Deterioration								
Within optimal	0.19**	-1.01***	0.03*	-39.68*	0.03	-0.63***	0.02	-38.42*
Optimal to suboptimal	0.61***	-1.76***	0.06***	-45.75**	0.32***	-1.06***	0.04**	-33.75
Within suboptimal	0.37***	-0.98**	0.11***	-33.81	0.29***	-0.63*	0.09***	-12.01
Improvement								
Within optimal	-0.16**	0.88***	-0.04***	37.08*	-0.05	0.56**	-0.04**	30.75
Suboptimal to optimal	-0.14*	0.58*	-0.02	30.00	-0.05	0.31	-0.01	9.58
Within suboptimal	-0.08	-0.07	0.02	73.91*	0.02	-0.08	0.03	-10.73

Model 1 adjusted for age, gender and baseline score of outcome variable, Model 2 also adjusts for baseline vision, ethnicity, wealth, subjective social status and self-rated health.

* p<0.05, ** p<0.01, *** p<0.001

5. Concluding comments

The research reported here examined the relationship between socioeconomic risk factors and the development of visual impairment in later life. It went on to examine the impact of change in visual acuity (both deterioration and improvement) on social, personal and economic outcomes in later life. It made use of longitudinal data provided by the English Longitudinal Study of Ageing (ELSA) to provide a more convincing analysis of causal mechanisms by clearly identifying the influence of socioeconomic factors on change in visual acuity, and the influence of change in visual acuity on subsequent changes in people's lives, marked by the social, personal and economic outcomes that we focussed on.

The findings identify clear and marked socioeconomic inequalities in both the onset of impaired vision and in the longer term patterning of change in visual acuity in later life. For example, in a survival analysis controlling for other risk factors, those in the poorest wealth quintile had a more than 50% higher risk of onset of moderate visual impairment than those in the highest wealth quintile and an almost 80% higher risk for onset of severe visual impairment. While, after adjusting for wealth differences, those in the lowest subjective social status quintile had more than twice the risk of onset of moderate vision impairment than those in the highest quintile, and an 80% higher risk of onset of severe visual impairment. Similarly, decreasing levels of wealth were associated with a decreased probability of having an optimal vision trajectory (stable excellent or good vision) and increased probability of having a suboptimal trajectory (fair, poor or declining vision). And subjective social status had a significant additional effect beyond that already accounted for by material wealth. For example, compared with the highest subjective social status quintile, those in the lowest subjective social status quintile were more than a fifth less likely to report stable excellent vision. These effects were present in models that adjusted for other important predictors of visual acuity, such as health behaviours, diagnosed disease, and demographic factors such as age, ethnicity and gender.

Findings also demonstrated the consequences of changes in visual acuity. Both deterioration and improvement in vision were related to changes in levels of wellbeing (depression and quality of life), social engagement and income over a two year period. Stronger associations with these outcomes were present for deteriorations in vision than improvements in vision. The largest effects were found for those whose vision deteriorated from optimal (excellent, very good or good) to suboptimal (fair or poor). For example, such a change led to a 29% rise in the number of depression symptoms, and a 19% fall in income. Although the size of these effects was reduced in fully adjusted models (by about half for depression and just over a quarter for income), they remained statistical significant. And, although effects were smaller, improvements in vision were associated with improvements in outcomes, especially for wellbeing outcomes. It is important to note here that these models only examined short term effects, over a two year period, the longer term impacts of change in visual acuity are likely to be larger.

Disentangling the mechanisms giving rise to increased risk of the onset of visual impairment in the older population is crucial for the development of appropriate policies to alleviate such inequalities. In particular, it has been argued that such information could be used to inform appropriately targeted interventions, increasing early detection of potentially treatable impairments (for example, refractive errors and cataracts through corrective lenses and surgery), and would therefore improve population health and reduce the individual and societal costs associated with vision loss (Ploubidis *et al*. 2011). In this study, the onset of diagnosed eye conditions was associated with trajectories of rapid deterioration in vision, fair vision, and poor vision. Timely diagnosis and treatment of eye diseases would, therefore, have the potential to substantially reduce the incidence of vision loss in older people. A number of eye diseases are detectable before symptoms present themselves to the individual, so regular eye examinations might play an important role.

The research presented here suggests that unequal access to treatment for eye disease might not be the crucial issue. For those with cataracts, socioeconomic factors were not related to the likelihood of having cataract surgery. The implication is that pathways to cataract surgery do not discriminate on the grounds of a household's financial circumstances either formally (through fee-for-service charges) or informally, within the NHS. By comparison, in the United States where there is a patchwork of public and private health insurance across the population, inequality in access to care leads to differential cataract surgery uptake (Goldzweig *et al*. 1997, Abraham *et al*. 2006, Williams *et al*. 2006).

However, the identification of eye disease and refractive errors, and treatment of refractive errors, are likely to be an issue. Although refractive error can often be corrected by the use of spectacles, contact lenses, or refractive surgery, it is frequently not identified nor adequately treated, making it a leading cause of visual impairment (Congdon *et al*. 2004, Midelfart *et al*. 2001). In particular those from lower social positions may well be at a greater risk of experiencing moderate or severe visual impairment as a consequence of not having regular eye examinations and the most current and correct prescription in their glasses or lenses.

Currently in England[1] everyone aged 60-69 is entitled to a free eye test every two years and those aged 70 and over are entitled to one every year. Despite these entitlements, in 2007 only 47% of people aged 60-69 reported having a biennial eye test and only 55% of people aged 70 and over had an annual eye test (Conway and McLaughlan 2007). As age increases, transportation problems are an increasingly reported barrier preventing regular eye tests (Conway and McLaughlan 2007). To address this, NHS-funded domiciliary eye tests are available and an eye test is carried out at home for no additional cost for those aged 60 and over who are unable to leave their home due to illness or disability. To help with the costs of glasses or contact lenses, NHS optical vouchers are available to individuals who need complex or powerful lenses and to recipients of certain state benefits. Where glasses or contact lenses cost more than the voucher value, the individual is required to pay the difference. Despite these supports, level of income has been found to be a significant barrier to regular eye tests in older people, with those in lower income brackets disproportionately dissuaded by the potential subsequent cost of glasses (Conway and McLaughlan 2007). Removing barriers to regular eye examinations and financial barriers to filling prescriptions would increase the likelihood of early identification and

[1] This is also the case in Wales and Northern Ireland, however in Scotland sight tests are free for all.

treatment of refractive errors and eye disease in poorer socioeconomic groups.

The findings reported here indicate that the risk and burden of vision loss are experienced disproportionately by those who are already socially disadvantaged, and that the development of visual impairment impacts adversely on social, economic and wellbeing outcomes. There is, therefore, a clear need for policy to focus on strategies to minimise socioeconomic risks for deterioration in visual acuity, to ensure equitable access to treatments to address visual impairment, including easy and free access to corrective lenses, and to mitigate the extensive and complex direct and indirect, financial and social costs of vision loss in older people.

Limitations

Some limitations exist in using ELSA for the analysis conducted here, two of which are worth returning to. First, it is not uncommon for longitudinal data to have missing responses for some items, or for respondents to leave the study. The problem of attrition is a particularly acute issue in a longitudinal study of older people as respondents are increasingly likely to leave the study due to poor health, cognitive impairment, institutionalisation, or death. Response to longitudinal surveys is not random and non-response bias is likely to accumulate over the follow-up period. Those who continue are generally healthier, wealthier and more socially connected than those who drop out. Although sample weights were used to correct for this non-response, it is possible that the weighting does not correct for all of the factors of interest. Consequently biases might remain in the analysis presented here.

In addition, the research used here relies on analysis of a self-reported measure of visual acuity. To examine the validity of such an approach to measurement we analysed data from The Irish Longitudinal Study of Ageing (TILDA) (Barratt et al. 2012). We conclude from this validation work that self-reported vision is a valuable and efficient measure of visual acuity. However, although it correlates well with an objective measure, it is better considered as a measure of the everyday, lived experience of vision, rather than an objective measure of visual acuity.

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