

Vision Impairment and Risk of Dementia: Findings from the English Longitudinal Study of Ageing

Hilary R. Davies-Kershaw, PhD,*[†] Ruth A. Hackett, PhD,*[‡] Dorina Cadar, PhD,*[§] Annie Herbert, PhD,*[¶] Martin Orrell, FRCPsych, PhD,*[‡] and Andrew Steptoe, DSc*

OBJECTIVES: To determine whether vision impairment is independently associated cross-sectionally and longitudinally with dementia.

DESIGN: Retrospective cohort study.

SETTING: English Longitudinal Study of Ageing.

PARTICIPANTS: Individuals aged 50 and older

MEASUREMENTS: Cross-sectional association between self-rated vision (poor or blind, moderate, normal) and dementia was analyzed, adjusting for potential confounders (sex, wealth, education, cardiovascular risk factors) using multivariable logistic regression. We also modelled the adjusted longitudinal association between vision impairment and dementia over an average of 11 years of follow-up using Cox proportional hazards regression for individuals aged 50 to 69 and those aged 70 and older.

RESULTS: After adjustment for confounders, participants who rated their vision as moderate were 2.0 (95% confidence interval (CI)=1.4–3.1) times as likely as those with normal vision to have dementia, and those who rated their vision as poor were 4.0 (95% CI=2.6–6.1) times as likely. Longitudinally, individuals aged 50 to 69 who rated their vision as moderate (1.8, 95% CI=1.0–3.0) or poor (3.6, 95% CI=1.1–11.8) were at greater risk of developing dementia than those who rated their vision as normal. There was no significant difference in risk in those aged 70 and older.

CONCLUSION: Our study confirms and extends findings from other countries, demonstrating cross-sectional associations between moderate and poor self-rated vision and dementia in England in all participants aged 50 and older and longitudinally over an 11-year period in those aged 50 to 69. These results help establish vision loss as a risk factor for dementia, although it is unclear why. Research

is needed to determine whether screening and treatment for vision loss may slow cognitive decline. *J Am Geriatr Soc* 66:1823–1829, 2018.

Key words: aging; vision impairment; dementia; epidemiology

The global estimate of individuals living with dementia was 46.8 million in 2015, with approximately 4.7 million in the United States and 676,000 in England.^{1,2} The estimated global annual cost of dementia is approximately \$818 billion, which is predicted to treble by 2040.^{1,2} Prevention of dementia has become a public health priority.^{3–5}

Vision loss affects approximately 2 million individuals in the United Kingdom, with 18% of those registered as blind or partly sighted.^{6,7} Age-related sensory changes such as hearing loss may be independently associated with development of dementia.^{8–12} Similarly, age-related vision impairment could lead to neuropathological changes.¹³ Cataracts, age-related macular degeneration (AMD), glaucoma, and diabetic-retinopathy contribute significantly to vision decline with aging and indicate neurodegeneration.¹⁴ As with hearing loss, vision impairment increases with age and has been found to be associated with social inequalities.¹⁵ The financial consequences of vision loss for the National Health Service are estimated to be £22 billion per year.¹⁶ Consequently, the Royal National Institute of Blind People recommend annual eye examinations for all individuals age 60 and older,¹⁷ but approximately 30% of women and 40% of men in this age group do not adhere to these recommendations, and those in lower-income households appear less likely to have regular eye tests.¹⁸

The U.S. Aging, Demographics and Memory Study (ADAMS) found evidence of an independent association between untreated poor vision and dementia.¹⁹ Other epidemiological studies conducted in the United States, the

From the *Department of Behavioural Science and Health, University College London, London, United Kingdom; [†]School of Health Sciences, University of Surrey, Guildford, United Kingdom; and the [‡]Institute of Mental Health, University of Nottingham, Nottingham, United Kingdom.

Address correspondence to Hilary Davies, Department of Behavioural Science and Health, University College London, London, United Kingdom. E-mail: h.davies.12@ucl.ac.uk

DOI: 10.1111/jgs.15456

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Netherlands, Australia, and Mexico have also suggested an association between age-related eye conditions and cognitive decline,^{20–26} but these studies have focused on cognitive decline rather than dementia,^{22–25} had small sample sizes,¹⁹ were not conducted in the United Kingdom, or analyzed only individuals aged 65 and older.^{21–25} The current study cross-sectionally and longitudinally investigated whether self-rated impaired vision was independently associated with dementia in a representative sample of adults aged 50 and older in England.

METHODS

Study Population

We used data from the English Longitudinal Study of Ageing (ELSA), a panel study established in 2002 as a parallel study to the Health and Retirement Study in the United States.²⁷ Face-to-face interviews and examination have been conducted in men and women aged 50 and older at 2-year intervals (wave 1 (2002–03) to Wave 7 (2014–15)) to obtain information on socioeconomic circumstances, physical and mental health, cognitive function, and biology as people age. Information on biomarkers and prescription data is collected every 4 years.²⁷

Outcome Measures: Dementia

We used 3 methods to identify individuals with dementia: a physician diagnosis of dementia that the participant or a caregiver reported between Wave 3 (2006–7) and 7 (2014–15); a score less than 3.5 on the adaptive Informant Questionnaire on Cognitive Decline in the Elderly (IQCODE)²⁸ (using a cut-off of 3.5 as an indirect measure of dementia to be consistent with previous studies²⁹) if a participant was unable to respond and the caregiver filled out the questionnaire to compare present functional performance with 2 years before;²⁸ or prescriptions for anticholinesterase inhibitors, N-methyl-D-aspartic acid receptor antagonists, and other relevant medication (galantamine, rivastigmine, memantine, donepezil, tacrine) to indicate dementia.^{30,31} If any of these 3 methods indicated dementia, the participant was considered to have dementia. For the cross-sectional and longitudinal analysis, we considered a participant to have dementia if this was indicated at any of Waves 3 to 7. Cases may not have a formal diagnosis of dementia, and our outcome was therefore physician-diagnosed dementia rather than incident dementia.³²

Exposure Measures

Self-Rated Vision

To assess visual function, ELSA participants were asked in Waves 1 to 7 to rate their eyesight (using glasses or corrective lenses as usual) as excellent, very good, good, fair, poor, or registered blind.³³ Individuals who did not rate their vision but were registered as partially sighted or blind with the local council were also included. We combined groups into 3 categories for analysis (excellent or very good=normal, good or fair=moderate, poor or

registered or legally blind=poor or blind). We used the self-rated vision measure from Wave 7 (2014–15) for the cross-sectional analysis and the measure from Wave 2 (2004–05) for the longitudinal analysis.

Covariates

Age was grouped into 2 categories (50–69, ≥ 70). Quintiles of nonpension wealth, as calculated by the Institute for Fiscal Studies, were used to derive a measure of economic status (1=low, 5=high).²⁷ Participants' highest education qualifications and smoking status were each categorized into three groups (1= no formal qualification, 2=intermediate education, 3=higher education; 1=never smoked, 2=exsmoker, 3=current smoker). Race (white vs nonwhite), doctor-diagnosed diabetes mellitus or hypertension, and a history of stroke were coded as binary.³⁴

Statistical Analysis

The sociodemographic and clinical risk profiles were summarized according to self-rated vision (between Waves 2 and 7). Chi-square tests were used to ascertain whether there were significant univariable differences between groups in the proportions of participants with dementia.

For adjusted cross-sectional and longitudinal analysis, we decided a priori on the basis of the existing literature that age, sex, race, wealth, and education were possible confounders. We also considered the following cardiovascular risk factors: smoking status, diabetes mellitus, hypertension, and history of stroke. The Health Survey for England has calculated weights to adjust for nonresponse bias; cross-sectional weights were derived for participants responding at each wave, and longitudinal weights were calculated using logistic regression models to estimate the probability of non-response using household- and individual-level data collected in the previous waves.^{34,35} We used relevant weightings to adjust for the cross-sectional and longitudinal analysis.²²

For the cross-sectional analyses, adjusted odds ratios (ORs) of diagnosed dementia (at any of Waves 3–7) for self-rated vision (at Wave 7) and 95% confidence intervals (CIs) were estimated using multivariable binary logistic regression. We used a forward stepwise approach (independent variables included in the order self-rated vision, sex, wealth, education, hypertension, stroke, diabetes mellitus, and smoking status (reference groups: normal vision; male; level 1 wealth; no qualifications; and no hypertension, stroke, diabetes mellitus, or smoking)) and performed likelihood ratio tests and used the Akaike Information Criterion (AIC) to select the model of best fit (which was the full model, p -value for likelihood test ratio test $< .001$, $AIC = 1,483.01$).^{36,37} Smoking status was therefore excluded from the model.

For the longitudinal analysis, adjusted hazard ratios (HRs) of diagnosed dementia (at Waves 3–7) for self-rated vision (at Wave 2) and 95% CIs were estimated using multivariable Cox proportional hazards regression. We considered the event to be any first diagnosis of dementia at Waves 3 to 7 and time to event to be time from Wave 2 to date or that first diagnosis in years. If the date of dementia diagnosis was not known, we used the midpoint date between the wave before the first dementia diagnosis was recorded and the wave at which it was recorded. For

Table 1. Participant Characteristics According to Self-Reported Vision (Wave 7: 2014–15)

Characteristic	Total Cohort (Wave 7), N = 7,685	Poor Self-Rated Vision or Blind, n = 1,081	Moderate Self-Rated Vision, n = 2,978	Normal Self-Rated Vision, n = 3,626	P-Value
	n (%)				
Dementia	194 (2.5)	80 (7.4)	78 (2.6)	36 (0.9)	<.001
Age					<.001
50–69	4,076 (53.0)	395 (36.5)	353 (12.0)	333 (9.0)	
≥70	3,609 (47.0)	686 (63.5)	2,060 (69.0)	863 (24.0)	
Female	4,302 (0.10)	639 (59.1)	1,726 (58.0)	1,937 (53.4)	<.001
Wealth quintile					<.001
1 (low)	1,292 (16.8)	318 (29.4)	552 (18.5)	422 (11.6)	
2	1,384 (18.0)	238 (22.0)	558 (18.7)	588 (16.2)	
3	1,632 (21.2)	218 (20.2)	637 (21.4)	777 (21.4)	
4	1,694 (22.0)	167 (15.5)	662 (22.2)	865 (23.9)	
5 (high)	1,683 (21.9)	140 (12.9)	569 (19.1)	974 (26.9)	
Nonwhite	261 (3.4)	54 (5.0)	124 (4.2)	83 (2.3)	<.001
Education					<.001
No qualification	1,838 (23.9)	442 (40.9)	782 (26.3)	614 (16.9)	
Intermediate	3,100 (40.3)	399 (36.9)	1,230 (41.3)	1,474 (40.7)	
Higher	2,747 (35.7)	240 (22.2)	966 (32.4)	1,541 (42.5)	
Diabetes mellitus	1,070 (13.9)	246 (22.8)	430 (14.4)	394 (10.9)	<.001
Hypertension	3,836 (49.9)	671 (62.1)	1,533 (51.5)	1,632 (45.0)	<.001
Stroke	457 (5.9)	137 (12.7)	183 (6.1)	137 (3.8)	<.001
Smoking status					<.001
Never	6,773 (88.1)	896 (82.9)	2,632 (88.4)	3,245 (89.5)	
Exsmoker	102 (1.3)	19 (1.8)	36 (1.2)	47 (1.3)	
Current	810 (10.5)	166 (15.4)	310 (10.4)	334 (9.2)	

participants who were not diagnosed with dementia by Wave 7, time to censoring was the time (in years) from Wave 2 to date of death (captured in ELSA up to February 2013) or drop out (if an individual dropped out of the study between waves, we used the date of the last interview), whichever was shortest. We used the Schoenfeld

residual test to examine the proportional hazards assumption of the models; there was insufficient evidence that this assumption had been violated (chi-square=6.60, degrees of freedom=12, p=.88).³⁸

All data were analyzed using STATA version 14 (Stata Corp LP, College Station, TX).

Table 2. Odds of Dementia According to Self-Reported Vision (Wave 7: 2014–15)

Characteristic	Model 1		Model 2		P-Value
	Odds Ratio (95% Confidence Interval)	P-Value	Odds Ratio (95% Confidence Interval)	P-Value	
Self-rated vision (reference group: normal)					
Moderate	2.68 (1.80–3.99)	<.001	2.04 (1.36–3.07)	<.001	<.001
Poor, blind	7.97 (5.34–11.88)	<.001	4.02 (2.64–6.13)	<.001	<.001
Aged ≥70 (reference group: 50–69)	6.40 (4.22–9.74)	<.001	4.60 (2.99–7.08)	<.001	<.001
Female	1.12 (0.84–1.50)	.43	0.99 (0.73–1.35)	.96	.96
Wealth quintile (reference group: 1)					
2	0.69 (0.47–1.02)	.07	0.86 (0.57–1.31)	.48	.48
3	0.56 (0.37–0.83)	.004	0.75 (0.49–1.15)	.19	.19
4	0.35 (0.22–0.54)	<.001	0.56 (0.34–0.92)	.02	.02
5	0.22 (0.13–0.38)	<.001	0.48 (0.26–0.86)	.01	.01
Education (reference group: no qualification)					
Intermediate	0.33 (0.23–0.46)	<.001	0.56 (0.39–0.80)	.001	.001
Higher	0.29 (0.20–0.42)	<.001	0.67 (0.44–1.02)	.06	.06
Diabetes mellitus	1.91 (1.36–2.68)	<.001	1.13 (0.79–1.63)	.51	.51
Hypertension	2.59 (1.89–3.56)	<.001	1.39 (0.99–1.94)	.06	.06
Stroke	7.38 (5.33–10.21)	<.001	3.77 (2.67–5.33)	<.001	<.001

Model 1 unadjusted.

Model 2 adjusted for age, sex, wealth, education, diabetes mellitus, hypertension and stroke

Sensitivity Analyses

Sensitivity analyses were conducted to test choices made regarding the longitudinal analyses (Cox regressions). We repeated the analyses, excluding new cases of dementia reported in Wave 3 (2006–07), to test the effect of defining our event as the first diagnosis of dementia, also adjusting for age-related eye diseases (glaucoma, diabetic retinopathy, macular degeneration, cataracts), to test whether they confounded associations between self-rated vision (or other covariates already in the model) and dementia.

RESULTS

Cross-Sectional Analyses

Ninety-five percent (7,865/8,253) of participants in 2014–15 rated their vision, with 47.2% ($n=3,636$) rating their vision as normal 38.7% ($n=2,978$) as moderate, and 14.1% ($n=1,081$) as poor or blind. A higher proportion of individuals in the poor or blind vision groups was female, was older, had less wealth and education, had a history of stroke and comorbidity involving diabetes mellitus or hypertension and were current smokers (Table 1).

There were 194 (2.5%) cases of dementia in 2014–15 (Table 1). After adjustment for potential confounders, participants with moderate self-rated vision were 2.0 (95% CI=1.4–3.1) times as likely to have a dementia diagnosis as those with normal vision, and those with poor self-rated were 4.0 (95% CI=2.6–6.1) times as likely (Table 2). Older age and previous stroke were independent risk factors for dementia diagnosis, and greater wealth and intermediate education seemed to have protective effects (Table 2).

Longitudinal analyses

Of the 8,648 core members in 2004–05, 3.6% rated their vision as poor or were blind. Poor vision or blindness was more common in women, older individuals, those with less wealth and education, those with diabetes mellitus and hypertension, and those with a history of stroke (Supplementary Table S1). Longitudinally, there were 275 incident cases of diagnosed dementia between Wave 2 (2004–05) and the end of Wave 7 (June 2015). There was a significant interaction between self-rated vision and age and its association with dementia ($p=.005$), so we stratified the analysis according to age (50–69, ≥ 70). During the mean follow-up (time to first dementia diagnosis, death, or drop-out) of 11 years, individuals in the younger group (50–69) and with moderate (HR=1.78, 95% CI=1.04–3.04) and poor (HR=3.60, 95% CI=1.10–11.78) self-rated vision were at greater risk of developing dementia than those with normal self-rated vision. Only diabetes mellitus was an additional independent risk factor (Figure 1). There was no significantly greater risk of developing dementia in any of the self-rated vision groups (moderate: HR=1.22, 95% CI=0.92–1.64; poor/blind: HR=1.24, 95% CI=0.69–2.22) (Figure 1) for the older group.

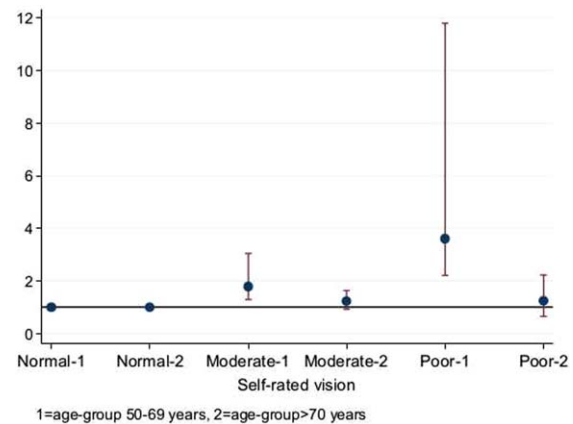


Figure 1. Hazard ratios of self-reported vision (normal, moderate, and poor or blind at Wave 2 (2004–05) and cumulative dementia (Waves 3–7 (2006–07 to 2014–15)) for age 50–69 (1) and 70 and older (2).

Sensitivity Analysis

The results were unchanged when excluding individuals who had been diagnosed with dementia in Wave 3 (2006–07). When age-related eye diseases were included in the Cox proportional hazards model, individuals in the younger group with moderate and poor self-rated vision were still at greater risk of developing dementia, although this was no longer significant (moderate: HR=1.54, 95% CI=0.86–2.73; poor/blind: HR=2.42, 95% CI=0.67–8.74) (Supplementary Table S2). The small number with poor vision and age-related eye disease who developed dementia could explain this. Similar to the original model fitted on the older age-group (≥ 70 years), when age-related eye diseases were included, there was no significant association between self-rated vision and risk of developing dementia.

DISCUSSION

Our study indicates that moderate and poor self-rated vision are cross-sectionally associated with physician-diagnosed dementia in a representative sample of English older adults (mean age 68), but longitudinally, after adjusting for multiple covariates, only individuals aged 50 to 69 with moderate and poor self-rated vision were at greater risk than those with normal vision of developing dementia. No longitudinal associations between vision and dementia were reported in the older age group.

Comparison with other studies

There have been no longitudinal studies of comparable size in the United Kingdom. Our findings build on a previous longitudinal study that used data from 625 participants in ADAMS, part of the HRS, to conduct a retrospective analysis of vision and cognitive decline.¹⁹ As with our findings, that cross-sectional analysis found an association between poor self-rated vision and dementia, but that study found that individuals aged 71 and older with poor vision had a 52% greater risk of developing dementia, particularly Alzheimer's disease.¹⁹ The HRS has

a demographic profile similar to that of ELSA, but unlike our study, the analysis did not include adults younger than 71, used age as a continuous variable, and included just 2 self-rated vision categories (better and worse vision).¹⁹ In addition, dementia was diagnosed in ADAMS through consensus judgements from an expert panel and so may have captured different cases from the ones included here.

A previous study tracked 2,087 adults aged 65 and older in the Australian Longitudinal Study for Ageing and measured change in visual acuity and in three cognitive outcomes: memory loss, verbal ability, and processing speed.²¹ The results suggested that visual decline was associated with memory decline but not verbal ability or processing speed.²¹ The authors suggested that change in memory loss may be associated with vision loss rather than decline in the cognitive process,²¹ but participants were followed for only up to 2 years, so no causal association could be determined. A later study in the same cohort followed 1,823 individuals for 8 years and showed that visual decline was associated with memory loss.³⁹ A prospective examination of 1,668 women aged 65 and older enrolled in the Study of Osteoporotic Fractures found, 4.5 years later, that women who had impaired visual acuity at baseline were twice as likely to decline cognitively and functionally.²⁰

The absence of a longitudinal association in participants aged 70 and older in our study might be because they had been managing their vision problems for longer,¹⁷ so the dual processes of vision and cognitive impairment might be more limiting on social engagement in early old age. In later old age, other factors such as loneliness may have a more significant effect, and visual problems may become less important.⁴⁰

Other work has focused more on specific types of eye conditions. A cross-sectional association was found between early and late age-related macular degeneration and cognitive impairment in the Blue Mountains Eye Study.²⁴ Older adults (≥ 75) in the Rotterdam study were followed for 4 years, and it was found that those with age-related maculopathy were at greater risk of developing Alzheimer's disease, although once covariates such as smoking and atherosclerosis were taken into account, the risk was no longer significant.⁴¹ A weak association was found between age-related maculopathy in participants aged 51 to 70 and impaired verbal fluency in the Atherosclerosis Risk in Communities Study.⁴² Another cross-sectional study analyzed data from the 11-center Age-Related Eye Disease Study and found a positive association between age-related macular degeneration, poor visual acuity, and poor cognitive function.²³ Findings from these studies suggest that there may be a common pathway for the neuronal degeneration that occurs in age-related maculopathy, macular degeneration, and cognitive decline.^{22,23,40,41}

Strengths and Limitations

An advantage of using ELSA is that it involves a large national representative sample of people aged 50 and older. The dataset includes repeated measures, so we were able to capture accumulative physician-diagnosed dementia cases and analyze time to diagnosis. The dataset also

includes measures of self-rated vision and other measures that could be controlled for in the analysis.

There were fewer dementia cases in the dataset than population estimates,^{43,44} primarily because of the identification of dementia on the basis of physician diagnoses in addition to IQCODE ratings because only a proportion of people living with dementia have had a formal diagnosis.⁴⁵ In addition, some items in the IQCODE may be confounding because individuals may score poorly because of visual impairment rather than cognitive decline (e.g. following a story in a book),²⁹ although there are no known reasons why dementia would be undercaptured to different degrees according to self-rated vision, and therefore it is likely that the associations found in this study would be present had more dementia cases been captured. Attrition bias is also relevant,²⁷ although we allowed for this by using probability weights for nonresponders.^{34,35}

An objective measure of visual acuity has not been collected in ELSA, but studies that have compared objective and self-rated measures have shown reasonable validity.⁴⁶ It has also been argued that self-rated vision overestimates visual impairment,⁴⁶ but considering the dose-response pattern of results detected in this study, this should not have affected our results, because individuals in the poor and moderate vision group had a higher risk of incident dementia than those reporting good vision.

Possible Mechanisms

Reporting of vision disturbances often precedes a diagnosis of dementia.⁴⁷ Symptoms include loss of visual acuity and color vision, changes in pupil response rate, reading difficulty, and problems with visuospatial orientation and recognizing objects.^{13,48} Beta-amyloid peptide deposits and specific genetic risk factors (apolipoprotein E and complement factor H) are present in individuals with dementia and age-related macular degeneration, and it has been suggested that the 2 disease have a common pathophysiology.^{13,48} In addition, as with hearing loss, vision impairment may impair visual cognition and perception, which could increase cognitive load.⁴⁹

Clinical Implications

Our longitudinal findings indicate that visual problems in individuals aged 50 to 69 may be associated with cognitive decline, and evidence suggests that improvements in vision could help delay neural degeneration.^{13,19} Individuals are more likely to have their eyes tested than their hearing,^{50,51} although a report that the UK College of Optometrists conducted found that, although people value their eye health, 5% of individuals aged 40 and older had not had an eye examination in the last 10 years.⁵¹ The Royal National Institute of Blind People recommendation for an annual eye examination for individuals aged 60 and older could potentially be extended to those aged 50 and older, which could have public health implications, because earlier identification and treatment of visual impairment may delay cognitive decline, although this assertion has not been tested.

In addition, activities such as reading and Internet use may become challenging for individuals with visual impairment, and evidence suggests that digital literacy may be protective against dementia in older adults.⁵²

Individuals who have Alzheimer's disease and difficulty identifying contrasting stimuli may benefit from enhancing contrast in the visual environment in their daily activities, for instance by improving the contrast of daily pill organizers, increasing the size and contrast of reading and recreational materials, and using high color contrast tableware at mealtimes.^{13,53,54} Visual impairment could also be an early indicator for testing for cognitive decline and dementia.

CONCLUSION

Our study supports the hypothesis that older adults with vision impairment have higher rates of dementia cross-sectionally (all ages) and are at greater risk of incident dementia longitudinally (<70 only). Screening for vision impairment may help identify individuals aged 50 to 69 who are at risk of cognitive decline. The public health implications are significant because more than 2 million U.K. adults have severe visual impairment. Further studies are needed to confirm the possible biological, psychological, and social mechanisms involved, and interventional evidence is required to examine whether treatment of vision impairment could delay or reduce the risk of dementia onset.

ACKNOWLEDGMENTS

The National Research and Ethics Committee granted ethical approval for all the ELSA waves (<http://www.nres.npsa.nhs.uk/>).

Financial Disclosure: This work was supported by the Promoting independence in Dementia study, which was funded by the U.K. Economic and Social Research Council (ESRC) and National Institute for Health Research (Grant ES/L001802/1). ELSA is funded by the National Institute on Ageing (Grant RO1AG7644) and a consortium of U.K. government departments coordinated by the ESRC. The data are lodged with the U.K. Data Archive.

Conflict of Interest: None.

Author Contributions: Study concept and design: HD, AS. Data analysis: HD, RH, DC, AH. Writing the manuscript: HD. Editing subsequent drafts: RH, AS, MO, DC, AH.

Sponsor's Role: The funders of the study had no role in the study design, data collection, data analysis, data interpretation, writing of the report, decision to publish, or preparation of the manuscript.

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SUPPORTING INFORMATION

Table S1: Descriptive statistics of self-reported vision (wave 2 (2004/05))

Table S2: Sensitivity analysis: Hazard ratios of self-reported vision at wave 2 and cumulative dementia (waves 3 (2006/07) to wave 7 (2014/15)) in 50–69-year-olds including age-related eye diseases.

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