What is the relationship between visual impairment and cognitive function in octogenarians?

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ABSTRACT

AIMS: To examine direct and indirect pathways between visual and cognitive function in advanced age.

METHODS: We analysed cross-sectional baseline data from *Life and Living in Advanced Age: A Cohort Study in New Zealand,* which recruited equal sample sizes of Māori (n=421) and non-Māori (n=516) octogenarians. The Modified Mini-Mental State Examination assessed cognitive function. Vision was assessed with self-report and measured distance visual acuity. Associations between visual and cognitive function were explored using general linear models and structural equation modelling.

RESULTS: Both Māori (mean age 82) and non-Māori (mean age 85) had good visual acuity [Māori: mean (standard deviation) 0.18 (0.20) logMAR; non-Māori 0.20 (0.17) logMAR] and cognitive function scores [Māori: median (interquartile range) 3MS=90 (11), non-Māori: 94 (8)]. Self-reported visual impairment was present almost 25% of the sample. Adjusting for confounders, no direct association was found between visual and cognitive function. For non-Māori, the path diagram showed the association between vision loss, and cognitive function was mediated by functional status.

CONCLUSION: Findings indicate that cognitive function is a multifactorial entity; rather than a direct effect of vision loss, mediating factors appear to contribute to cognitive decline in advanced age.

With the world population ageing rapidly, healthy ageing becomes a global priority. Cognitive function is one of the main factors defining how successfully we age.[1] The prevalence of dementia is projected to increase dramatically in the near future.[2] Various modifiable risk factors for dementia have been established, such as depression, physical and cognitive function, engagement in social and productive activities, and medical conditions including diabetes mellitus.[3,4] Of particular interest is vision loss, common in old age and often treatable. There is growing evidence for a possible (predictive) association between vision loss and poorer cognitive function in advanced age,[5–8] but the mechanism behind this association remains to be fully understood. Besides a direct relationship, studies also reported on associations between vision loss and several other risk factors for cognitive decline, including functional status, medical conditions, social relationships and depression.[9–11] This suggests that the relationship between cognitive function and poor vision is to some extent mediated by interrelated factors. Because better understanding of the relationship between vision and cognition could lead to interventions for maximising cognitive function in late life, we aimed to explore the direct and indirect relationships between vision loss and cognitive function in an older New Zealand population, utilising data from Te Puāwaitanga o Nga Tapuwae Kia Ora Tonu - Life and Living in Advanced Age: A Cohort Study in New Zealand (LiLACS NZ).

Methods

Study population and data collection

LiLACS NZ is an ongoing longitudinal population-based cohort study of those in advanced age.[12,13] The study was started in 2010, eligible individuals were those living within the Lakes and Bay of Plenty District Health Board geographical boundaries, aged 80 to 90 years for Māori and aged 85 years for non-Māori. Different age criteria applied between the two cohorts due to a large disparity in longevity for Māori.[14]

Participants were identified from the New Zealand general and Māori electoral rolls; primary care databases; whānau and community networks. The study recruited 421 Māori and 516 non-Māori.

All participants underwent an annual interviewer-administered standardised questionnaire (brief or comprehensive) and physical assessment, conducted by trained interviewers and research nurses during a home visit or at another site as the participant chose. Medical conditions were identified by self-report, general practice and hospital records, physical assessment and blood analysis. A detailed description of LiLACS NZ study design and recruitment strategies has been reported elsewhere.[12,13]

The current study uses the baseline data. The study sample comprises only participants who completed the comprehensive interview, which included cognitive function assessment.

The study was approved by the Northern X Regional Ethics Committee of New Zealand Ministry of Health in December 2009 (NXT 09/09/088). Written informed consent was obtained from all participants before enrolment.

Measures

Cognitive function: The Modified Mini-Mental State Examination (3MS)[15] was used to assess global cognitive status. The 3MS is a screening instrument for dementia, with components assessing orientation to time and place, registration, memory, language and construction. To adjust for vision loss for those who were blind or had self-reported vision loss, we omitted similar items as in the Mini-Mental State Examination—blind version,[16] a validated cognitive test for the visually impaired: naming of the appointed item or body part; following a written command; writing a sentence; copying a drawing; performing a three-stage command. Scores range from 100 (best) to 0 (worst).

Visual impairment: Vision loss was administrated with both self-report and measured visual acuity. Binocular distance visual acuity was measured using the three metre 2000 series revised ETDRS chart. The test conditions were standardised: illumination was measured with a preferred minimum of 350 lux and participants were encouraged to wear corrective glasses during the test if glasses were normally worn. This habitual visual acuity was recorded as the smallest line read correctly plus additional letters read correctly. Acuity scores were converted to the logarithm of the minimum angle of resolution (logMAR) to transform the data to an approximately normal distribution.[17] A single self-reported item, modified from the Cognitive Function and Ageing studies[18] was used to assess subjective disability caused by vision loss. Participants were asked whether their vision loss interfered with normal day-to-day functioning, “yes” or “no”.

Covariates

Socioeconomic-demographic information (age, gender, ethnicity, education level and socio-economic deprivation) was determined from the comprehensive questionnaire. Socio-economic deprivation was reflected in the New Zealand Deprivation Index derived from the address at recruitment.[19] Baseline functional status was assessed with the Nottingham Extended Activities of Daily Living scale (NEADL), a self-reported 22-item scale validated as an assessment of functional disability in domestic tasks, mobility, leisure activities and kitchen-related tasks.[20] Participants were asked whether they did perform the activities on their own, with help or were unable to do them. Scores range from 0 at worst to 22 at best. Depression was assessed using the 15-question version of the Geriatric Depression Scale (GDS-15), a screening test for depressive symptoms in older people.[21] The scale consists of 15 items, of which participants were asked how they have felt the past week. Higher scores indicate more depressive symptoms. Comorbidity was determined by summing the number of chronic conditions.[22] Data about participants’ engagement in social

activities during the previous month were obtained from an index of nine questions on how often they had: "Attended meetings of any community/neighbourhood or social groups, such as old people's clubs, lectures or anything like that?", "Attended any religious meeting?", " Been a spectator at a sports event?", "Gone to an entertainment or arts event, such as concert, theatre or cinema?", "Gone to a restaurant, café, pub or bar?", "Attended a family event?", "Attended a social occasion, such as a barbeque or hangi?", "Gone to the library or museum?". Answers were dichotomised into participated (those who reported "every day" to "occasionally") or no participation (those who reported "not at all" for all questions).

Statistical analyses

Separate analyses were conducted for Māori and non-Māori, as previous research showed differing health profiles and life expectancies between the two cohorts.[14] Descriptive statistics are presented for all variables. For categorical variables, frequency and percentage are presented. For continuous variables, the mean (standard deviation (*SD*)) or median (interquartile range (*IQR*)) is presented; depending on whether the variable was normally distributed or not.

General linear models (GLM) were used to determine the direct association between visual impairment and cognitive function while adjusting for covariates. Covariates that were associated with 3MS score in univariate models with a *p*-value <0.2 were included in multivariate models. These were social engagement, functional status and depressive symptoms (and comorbidity for Māori). Age was not included in the multivariate models for non-Māori because all participants were 85 years old at baseline. Due to the skewed distribution of 3MS scores, we inversed and log-transformed 3MS scores to establish a normally distributed score (Log (100 - 3MS score)). Back-transformed beta-correlation coefficients are presented in the tables.

In the GLMs, inversed log-transformed 3MS was entered as the dependent continuous variable and visual impairment (either self-reported or visual acuity) as the independent variable. Models were repeated replacing visual acuity (continuous variable) with self-reported visual impairment (categorical variable). A *p*-value <0.05 was considered statistically significant. Data were analysed using the Statistical Package for the Social Sciences (SPSS) for Windows (IBM SPSS version 21).

Structural equation modelling (SEM) was used to produce path diagrams modelling direct and indirect pathways between either visual acuity or self-reported vision loss and cognition via intermediate variables. The 3MS scores were entered as the continuous dependent variable. Those covariates significantly associated with 3MS score in the GLMs were included as confounders. The strength of the relationship between two variables was estimated as a standardised regression weight (ie, path coefficient, *Beta*). While there is no established guideline regarding sample size requirements for structural equation modelling, a general rule of thumb is that the minimum sample size should ideally be 20 times the number of variables in the model.[23] The model generated in this study consisted of five variables and thus the non-Maori sample size of sample of 402 was sufficient for path analysis. Model fitness was assessed by the ratio of chi-squared to degrees of freedom (Ratio of Chi-square/df), the root mean square error of approximation (RMSEA), the Tucker Lewis Index (TLI) and the Comparative Fit Index (CFI). The following values indicate a good fit; for the Ratio of Chi-square/df, a value of <3, for RMSEA a value close to 0.05, for TLI a value that approaches 1, for CFI a value >0.95. The product of estimates along each path reflects the total effect of that compound in the path diagram. Then, the total indirect and direct causal effect of vision on cognition is the sum of the estimates of all the separate paths. The path analysis was performed using IBM SPSS Amos version 22.0 (IBM Corp, Armonk, New York, USA). Significant levels were set at p<0.05.

Results

At baseline, 661/937 participants (259 Māori, 402 non-Māori) completed the comprehensive interview, of which 649 (258 Māori, 391 non-Māori) participants had their cognition tested. After excluding four participants from the analysis because of incorrect visual acuity measurement, visual acuity was tested in 554 participants (210 Māori, 344 non-Māori); 650 (253 Māori, 397 non-Māori) reported on their vision loss.

Table 1: Baseline characteristics of participants.

Variables	Māori n=259	Non-Māori n=402
Gender	**n (%)**	
Male/Female	104 (40)/155 (60)	189 (47)/213 (53)
Education level		
Primary school or no schooling	73 (29)	62 (16)
Secondary school, no qualification	94 (37)	137 (35)
Secondary school qualification	46 (18)	85 (22)
Post-secondary schooling	38 (15)	110 (28)
Socio-economic deprivation (NZ Dep. index)[24,a]		
1–4 (low)	37 (14)	103 (26)
5–7 (medium)	61 (24)	173 (43)
8–10 (high)	161 (62)	126 (31)
Engagement in social activities[e]	234 (93)	377 (94)
Ocular disease		
Cataract	131 (53)	247 (62)
Glaucoma	27 (11)	45 (11)
ARMD	40 (16)	72 (19)
Diabetic eye disease	19 (8)	7 (2)
Measured visual impairment (>0.3 logMAR)[g]	46 (22)	66 (19)
Self-reported visual impairment[h]	69 (27)	95 (24)
Cognitive impairment (3MS≤77)[25]	39 (15)	25 (6)
Mean (SD)		
Age in years	82.3 (2.7)	84.6 (0.5)
Comorbidity (number of conditions)[b]	4 (2)	4 (2)
Distance visual acuity (logMAR)[f]	0.18 (0.20)	0.20 (0.17)
Median (IQR) Min, Max		
Cognitive function (3MS)[i]	90 (11) 1, 100	94 (8) 12, 100
Functional status (NEADL score)[c]	19 (4) 0, 22	19 (3) 1, 22
Depressive symptomatology (GDS-15 score)[d]	2 (3) 0, 14	2 (2) 0, 10

Abbreviations: *SD*, standard deviation; *IQR*, interquartile range; NZ Dep. Index, New Zealand deprivation index; NEADL, Nottingham Extended Activities of Daily Living scale; GDS-15, Geriatric Depression Scale-15 items; ARMD, Age-Related Macular Degeneration; logMAR, logarithm of the Minimum Angle of Resolution; 3MS, the Modified Mini Mental State Examination.

[a] Derived from the address at recruitment.

[b] Derived from an index of 15 selected chronic conditions.

[c] NEADL scores ranging from 0 (at worst) to 22 (at best).

[d] GDS-15 scores, higher scores indicate more depressive symptoms.

[e] Participants who participated in any of nine predefined social activities.

[f] Higher scores indicates worse visual acuity.

[g] The minimum visual acuity required for an unrestricted driver's license in New Zealand.[26]

[h] Participants who reported their vision interfered with normal day-to-day functioning.

[i] 3MS scores ranging from 0 (at worst) and 100 (at best).

Table 2: Association between cognitive function and visual impairment using general linear models.[a,b]

Variables	Beta[c]	95% CI	p-values	Back transformed Beta
Māori				
Distance visual acuity (logMAR)	0.103	-0.217, 0.422	0.526	-1.267
Self-reported visual impairment[d]	0.110	-0.030, 0.251	0.123	-1.289
Non-Māori				
Distance visual acuity (logMAR)	0.197	-0.120, 0.515	0.223	-1.574
Self-reported visual impairment[d]	0.065	-0.056, 0.187	0.290	-1.163

Abbreviations: 95% *CI*, 95% confidence interval; logMAR, logarithm of the Minimum Angle of Resolution.
[a] Models were adjusted for: gender, education level, socio-economic deprivation, social engagement, functional status and depressive symptoms (and age, comorbidity for Māori).
[b] A *p*-value of less than 0.05 (two tailed test) was considered statistically significant.
[c] Estimates from the inversed log transformed 3MS scores.
[d] Reference group are participants who reported that their vision did not interfere with day-to-day functioning.

Baseline characteristics of Māori and non-Māori participants are presented in Table 1. Among Māori, 40% were male; mean (*SD*) age was 82.3 (2.7) years. Non-Māori participants had a mean (*SD*) age of 84.6 (0.5) years; 47% were male. Median *(IQR*) 3MS scores were 90 (11) and 94 (8) for Māori and non-Māori, respectively.

More than one-quarter (n=69) of Māori participants and 24% (n=95) of non-Māori participants reported their eyesight interfered with their normal day-to-day functioning. The majority of participants had good visual acuity, with mean (SD) visual acuity scores of 0.18 (0.20) logMAR for Māori and 0.20 (0.17) logMAR for non-Māori. In addition, 22% (n=46) Māori and 19% (n=66) non-Māori could be regarded as having measured visual impairment; a visual acuity <0.3 logMAR is an often used cut-off point and the minimum visual acuity required for an unrestricted driver's license in New Zealand.

In unadjusted GLM, self-reported visual impairment was significantly associated with 3MS scores in the Māori (*Beta*=0.150, *CI*=[0.012, 0.289], *p*=0.033). A non-significant trend was found for non-Māori (*Beta*=0.118, *CI*=[-0.002, 0.239], *p*=0.054). Visual acuity scores were not significantly associated with 3MS scores in both cohorts (Māori: *Beta*=0.202, *CI*=[-0.104, 0.509], *p*=0.194; non-Māori: *Beta*=0.285, *CI*=[-0.031, 0.602], *p*=0.077).

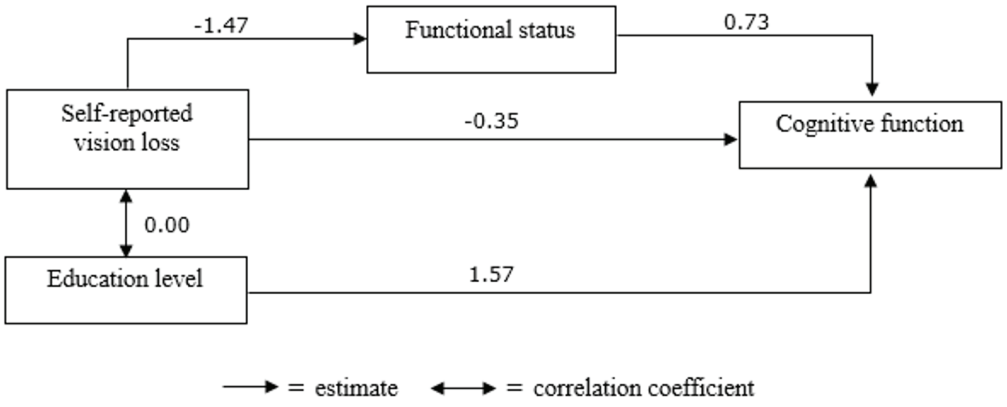
Table 2 shows associations between vision and cognition for each cohort after adjusting for multiple covariates. Both self-reported vision loss and measured visual acuity were no longer significantly associated with 3MS scores in both Māori and non-Māori.

Since certain conditions may play more of a role than others on cognitive decline, we repeated analyses replacing comorbidity by hypertension, diabetes, stroke and cardiovascular disease, all known risk factors for dementia.[3,27] However, no significant associations between these health conditions and cognitive function were found in the final models for both cohorts (data not shown).

In contrast to visual impairment, some other variables of interest were independently associated with the 3MS scores in the multivariable adjusted models. Significant predictors of poorer cognitive function in Māori included male gender and more depressive symptoms; post-secondary education level was associated with better cognition (Tables 3 and 5). For non-Māori participants, more education and better functional status were significantly associated with better cognitive function (Tables 4 and 6). The role of these variables in the relationship between vision and cognition was further explored using SEM to produce corresponding path diagrams.

Cognition was placed in the structural equation model as the outcome variable. Vision loss (either measured or self-reported), education, and for Māori only gender, were modelled with direct effects. The indirect effect of either self-reported or measured distance visual acuity on cognitive function was mediated through functional status in the non-Māori cohort (Figures 1A, 1B) and through depressive symptoms in the Māori cohort (Figure 2A, Table 4).

Figure 1A: [a]Path diagram for the direct and indirect relationship between self-reported vision loss and cognitive function in the non-Māori cohort.

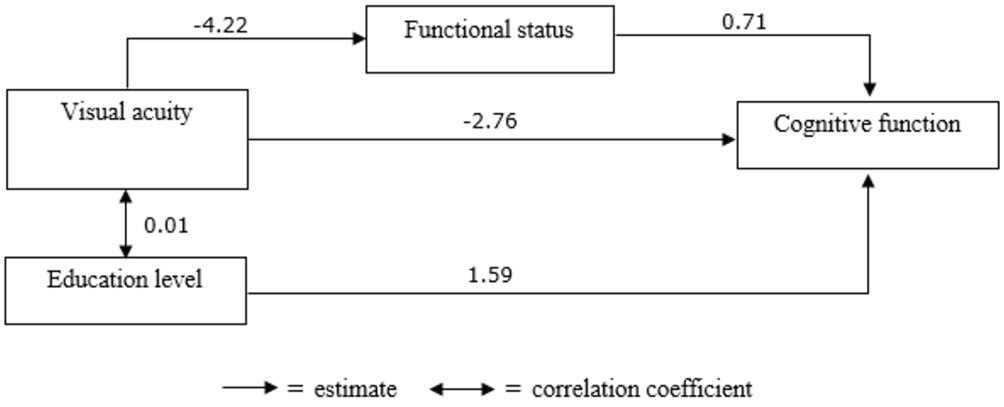


Total indirect effect via functional status: -1.07, total indirect and direct effect: -1.42. No correlation between vision and education level.
[a] Ratio chi-squared degrees of freedom (*Chi-square*/df) = 0.113, root mean square error of approximation (RMSEA)= 0.000, Tucker Lewis Index (TLI)= 1.108, comparative fit index (CFI)= 1.000.

Of the path diagrams produced, only the path diagrams including non-Māori did fulfil all assumptions for fitness of the model (Figures 1A, 1B).

Both path diagrams illustrated that the relationship between cognitive function and poor vision is to some extent mediated by functional status. Self-reported vision loss was directly associated with a decline of 0.35 points on the 3MS; measured visual acuity with a decline of almost three points. The indirect pathway from self-reported vision loss to cognitive function via functional status was associated with a total decline of 1.07 points on the 3MS and with a total decline or 3.00 points in the path diagram with measured visual acuity. Together, self-reported vision loss decreases 3MS scores through indirect and direct pathways with 1.42 points; measured visual acuity demonstrated a total combined direct and indirect effect of almost six points (6%) decline on the 3MS. However, higher education was independently associated with an increase of 3MS scores; vision loss was not correlated with education level in this path diagram.

Figure 1B: [a]Path diagram for the direct and indirect relationship between measured visual acuity and cognitive function in the non-Māori cohort.



Total indirect effect via functional status: -3.00, total indirect and direct effect: -5.76. No correlation between vision and education level.
[a] Ratio chi-squared degrees of freedom (*Chi-square*/df) = 0.248, root mean square error of approximation (RMSEA)= 0.000, Tucker Lewis Index (TLI)= 1.162, comparative fit index (CFI)= 1.000.

Discussion

This study aimed to examine the impact and pathways by which vision loss affects cognitive function in advanced age. In line with previous cross-sectional and longitudinal studies, we found neither self-reported nor measured visual impairment was independently associated with cognition.

However, the path analyses confirmed that the relationship between vision loss and cognitive function was explained by functional status in the non-Māori cohort. This may be best explained by 'the common cause hypothesis' (common age-related factor is responsible for both vision loss and cognitive decline), where functional status serves as the age-related common cause. The SEM findings can also be explained by 'the sensory deprivation hypothesis' (assumes that cognitive decline is caused by changes in the brain as a result of diminished sensory input; sensory loss reduces the opportunity to engage in cognitively stimulating activities).[28] Note that the path diagram does not provide information on the direction of associations. Persons with poor functional status may be less likely to see an optometrist. They also may be less able to participate in social and cognitively stimulating activities, suffer from more depressive symptoms and be less physically active. Baseline disability in activities of daily living have been linked to dementia incidence, and vice versa, dementia also may predict functional disability.[29,30]

In the cross-sectional survey of the Blue Mountains Eye Study (BMES) with participants aged 50+, visual impairment was associated with higher odds of cognitive impairment.[31] However, no association observed between visual impairment and cognitive decline at five and 10 years follow-up in this BMES population.[32] Similarly, the Hispanic Established Populations for Epidemiologic Studies of the Elderly found no relationship between distance visual impairment and change in MMSE-blind scores over a seven-year period; only near vision impairment conferred an increased 0.13 points annual decline in MMSE-blind scores compared to those with adequate near vision.[7] In a six-year follow up of a cohort of older Dutch people (baseline mean age 65), Valentijn et al (2005) concluded that the deterioration of visual acuity was associated with deterioration in cognitive measures and attributed the positive relationship to the reduced ability of participants with sensory impairments to perform well on executive function domain on the cognitive test.[33] Elyashiv, Shabtai and Belkin (2014) found an attenuated association between vision and cognition with advanced ageing and postulated that increased impact of other risk factors for cognitive decline mask the impact of visual impairment on cognitive function in older age.[5] Both propositions comply with the previously hypothesised explanations for the relationship between vision and cognition.[28,33]

The high median 3MS scores in the LiLACS NZ cohort may have reduced the power to observe a direct relationship with visual impairment. Using a cut-off point of 3MS ≤77 to define cognitive impairment, only 15.1% (n=39) of Māori and 6.4% (n=25) of non-Māori would have been considered cognitive impaired.[25] Other limitations of this study include its reliance on the inclusion of only those participants who completed the comprehensive questionnaire; this could have introduced a selection bias towards a healthier sample.[14] It is unclear if omitting items not independent of vision will lead to under or overestimation of cognitive performance among those with visual impairment contributing to a type II error. The study by Busse et al reported that the validity of the vision-adjusted MMSE (MMSE-blind) is comparable to the full MMSE.[16] We assume similar observation between the full and vision-adjusted 3MS; future studies are needed to examine this. Lastly, causal inference cannot be established from this cross-sectional analysis. The strengths of this study derive from its large collection of comprehensive health and social data; the separate analyses for indigenous people, which strengthened generalisability to older Māori; and the assessment of both measured and self-reported visual impairment. These results address the literature gaps on vision and cognitive function in older indigenous people and octogenarians.

In conclusion, we found that rather than a direct effect of vision loss, mediating factors appear to contribute to cognitive decline in advanced age. Further longitudinal research is needed to examine the role of sensory function and mediating factors, on cognitive function over time. Findings from this research are able to inform policies on health and social living of older people, particularly extending relevant information to people of advanced age.

Appendix

Table 3: Adjusted association between cognitive function and self-reported visual impairment in the Māori cohort (n=187).[a,b]

Variables	*Beta*[c]	95% *CI*	*p*-values	Back transformed *Beta*
Self-reported visual impairment[d]				
No	Reference category			
Yes	0.110	-0.030, 0.251	0.123	-1.289
Age	0.011	-0.013, 0.036	0.373	-1.026
Gender				
Male	Reference category			
Female	-0.216	-0.344, -0.089	0.001	0.608
Education level				
Primary school or no schooling	Reference category			
Secondary school, no qualification	-0.121	-0.276, 0.034	0.126	0.757
Secondary school qualification	-0.145	-0.334, 0.043	0.131	0.716
Post-secondary schooling	-0.402	-0.610, -0.193	<0.001	0.397
Socio-economic deprivation (NZ Dep. index)[34,e]				
1–4 (low)	Reference category			
5–7 (medium)	-0.031	-0.246, 0.184	0.774	0.930
8–10 (high)	-0.108	-0.298, 0.083	0.268	0.781
Comorbidity (number of conditions)[f]	0.009	-0.021, 0.039	0.552	-1.021
Engagement in social activities[g]				
No	Reference category			
Yes	-0.022	-0.312, 0.269	0.883	0.951
Functional status (NEADL score)[h]	0.001	-0.017, 0.020	0.896	-1.003
Depressive symptomatology (GDS-15 score)[i]	0.046	0.009, 0.083	0.016	-1.111

Abbreviations: 3MS, modified mini-mental state examination; *SE*, standard error; 95% *CI*, 95% confidence interval.
[a] Models were adjusted for: age, gender, education level, socio-economic deprivation, comorbidity, social engagement, functional status and depressive symptoms.
[b] A *p*-value of less than 0.05 (two tailed test) was considered statistically significant.
[c] Estimates from the inversed log transformed 3MS scores.
[d] Participants who reported their vision interfered with normal day-to-day functioning.
[e] Derived from the address at recruitment.
[f] Derived from an index of 15 selected chronic conditions.
[g] Participants who participated in any of nine predefined social activities.
[h] NEADL scores ranging from 0 (at worst) to 22 (at best).
[i] GDS-15 scores, higher scores indicate more depressive symptoms.

Table 4: Adjusted association between cognitive function and self-reported visual impairment in the non-Māori cohort (n=380).[a,b]

Variables	*Beta*[c]	95% *CI*	*p*-values	Back transformed *Beta*
Self-reported visual impairment[d]				
No	Reference category			
Yes	0.065	-0.056, 0.187	0.290	-1.163
Gender				
Male	Reference category			
Female	-0.052	-0.153, 0.048	0.306	0.886
Education level				
Primary school or no schooling	Reference category			
Secondary school, no qualification	-0.158	-0.309, -0.008	0.039	0.694
Secondary school qualification	-0.288	-0.452, -0.123	<0.001	0.515
Post-secondary schooling	-0.245	-0.403, -0.086	0.003	0.569
Socio-economic deprivation (NZ Dep. index)[34,e]				
1–4 (low)	Reference category			
5–7 (medium)	0.027	-0.098, 0.153	0.668	-1.065
8–10 (high)	0.082	-0.053, 0.217	0.233	-1.207
Engagement in social activities[f]				
No	Reference category			
Yes	-0.130	-0.372, 0.112	0.290	0.741
Functional status (NEADL score)[g]	-0.021	-0.039, -0.004	0.017	0.952
Depressive symptomatology (GDS-15 score)[h]	0.021	-0.009, 0.052	0.170	-1.050

Abbreviations: 3MS, modified mini-mental state examination; *SE*, standard error; 95% *CI*, 95% confidence interval.
[a] Models were adjusted for: gender, education level, socio-economic deprivation, social engagement, functional status and depressive symptoms.
[b] A p-value of less than 0.05 (two tailed test) was considered statistically significant.
[c] Estimates from the inversed log transformed 3MS scores.
[d] Participants who reported their vision interfered with normal day-to-day functioning.
[e] Derived from the address at recruitment.
[f] Participants who participated in any of nine predefined social activities.
[g] NEADL scores ranging from 0 (at worst) to 22 (at best).
[h] GDS-15 scores, higher scores indicate more depressive symptoms.

Table 5: Adjusted association between cognitive function and distance visual acuity in the Māori cohort (n=174).[a,b]

Variables	*Beta*[c]	95% *CI*	*p*-values	Back transformed *Beta*
Distance visual acuity (logMAR)	0.103	-0.217, 0.422	0.526	-1.267
Age	0.009	-0.016, 0.034	0.482	-1.021
Gender				
Male	Reference category			
Female	-0.155	-0.284, -0.025	0.020	0.701
Education level				
Primary school or no schooling	Reference category			
Secondary school, no qualification	-0.074	-0.235, 0.087	0.366	0.843
Secondary school qualification	-0.108	-0.304, -0.088	0.278	0.780
Post-secondary schooling	-0.281	-0.500, -0.061	0.013	0.524
Socio-economic deprivation (NZ Dep. index)[34,d]				
1–4 (low)	Reference category			
5–7 (medium)	-0.018	-0.241, 0.206	0.875	0.960
8–10 (high)	-0.106	-0.305, 0.092	0.292	0.783
Comorbidity (number of conditions)[e]	0.003	-0.026, 0.033	0.820	-1.008
Engagement in social activities[f]				
No	Reference category			
Yes	-0.008	-0.295, 0.279	0.956	0.981
Functional status (NEADL score)[g]	-0.014	-0.034, 0.005	0.152	0.967
Depressive symptomatology (GDS-15 score)[h]	0.043	0.004, 0.081	0.029	-1.103

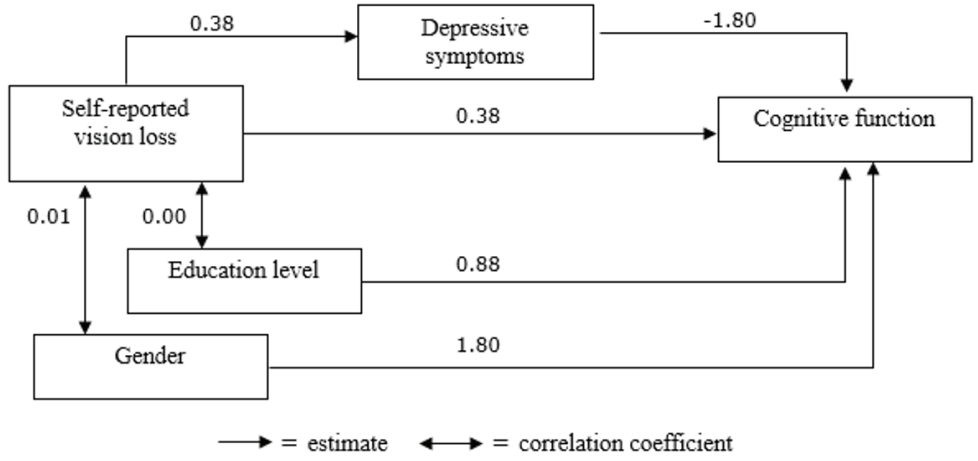
Abbreviations: 3MS, modified mini-mental state examination; *SE*, standard error; 95% *CI*, 95% confidence interval; logMAR, logarithm of the Minimum Angle of Resolution.
[a] Models were adjusted for: age, gender, education level, socio-economic deprivation, comorbidity, social engagement, functional status and depressive symptoms.
[b] A p-value of less than 0.05 (two tailed test) was considered statistically significant.
[c] Estimates from the inversed log transformed 3MS scores.
[d] Derived from the address at recruitment.
[e] Derived from an index of 15 selected chronic conditions.
[f] Participants who participated in any of nine predefined social activities.
[g] NEADL scores ranging from 0 (at worst) to 22 (at best).
[h] GDS-15 scores, higher scores indicate more depressive symptoms.

Table 6: Adjusted association between cognitive function and distance visual acuity in the non-Māori cohort (n=337).[a,b]

Variables	***Beta*[c]**	**95% *CI***	***p*-values**	**Back transformed *Beta***
Distance visual acuity (logMAR)	0.197	-0.120, 0.515	0.223	-1.574
Gender				
Male	Reference category			
Female	-0.008	-0.113, 0.098	0.885	0.982
Education level				
Primary school or no schooling	Reference category			
Secondary school, no qualification	-0.163	-0.319, -0.007	0.041	0.687
Secondary school qualification	-0.297	-0.466, -0.127	<0.001	0.505
Post-secondary schooling	-0.239	-0.404, -0.074	0.005	0.577
Socio-economic deprivation (NZ Dep. index)[34,d]				
1–4 (low)	Reference category			
5–7 (medium)	0.070	-0.062, 0.203	0.298	-1.176
8–10 (high)	0.095	-0.047, 0.238	0.188	-1.246
Engagement in social activities[e]				
No	Reference category			
Yes	-0.136	-0.422, 0.150	0.350	0.731
Functional status (NEADL score)[f]	-0.019	-0.039, 0.065E^-5	0.049	0.956
Depressive symptomatology (GDS-15 score)[g]	0.024	-0.009, 0.056	0.148	-1.056

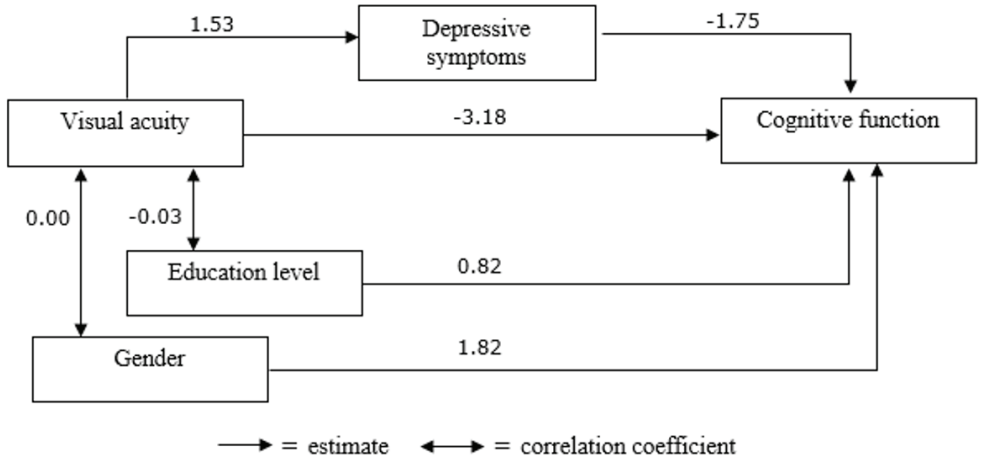
Abbreviations: 3MS, modified mini-mental state examination; *SE*, standard error; 95% *CI*, 95% confidence interval, logMAR, logarithm of the Minimum Angle of Resolution.
[a] Models were adjusted for: gender, education level, socio-economic deprivation, social engagement, functional status and depressive symptoms.
[b] A p-value of less than 0.05 (two tailed test) was considered statistically significant.
[c] Estimates from the inversed log transformed 3MS scores.
[d] Derived from the address at recruitment.
[e] Participants who participated in any of nine predefined social activities.
[f] NEADL scores ranging from 0 (at worst) to 22 (at best).
[g] GDS-15 scores, higher scores indicate more depressive symptoms.

Figure 2A: [a]Path diagram for the direct and indirect relationship between self-reported vision loss and cognitive function in the Māori cohort.



[a] Ratio chi-squared degrees of freedom (χ2/df)=3.493, root mean square error of approximation (RMSEA)=0.100, Tucker Lewis Index (TLI)=0.290, comparative fit index (CFI)=0.787.

Figure 2B: [a]Path diagram for the direct and indirect relationship between distance visual acuity and cognitive function in the Māori cohort.



[a] Ratio chi-squared degrees of freedom (χ2/df)=2.954, root mean square error of approximation (RMSEA)=0.089, Tucker Lewis Index (TLI)=0.128, comparative fit index (CFI)=0.826.

Competing interests:
Nil.

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REFERENCES:

1. Rowe JW, Kahn RL. Successful aging. Gerontologist. 1997; 37(4):433–40.
2. Prince M, Bryce R, Albanese E, et al. The global prevalence of dementia: A systematic review and metaanalysis. Alzheimer's & Dementia. 2013; 9(1):63–75.e2.
3. Baumgart M, Snyder HM, Carrillo MC, et al. Summary of the evidence on modifiable risk factors for cognitive decline and dementia: A population-based perspective. Alzheimers Dement. 2015; 11(6):718–26.
4. Wang HX, Karp A, Winblad B, Fratiglioni L. Late-life engagement in social and leisure activities is associated with a decreased risk of dementia: a longitudinal study from the Kungsholmen project. Am J Epidemiol. 2002; 155(12):1081–7.

5. Elyashiv SM, Shabtai EL, Belkin M. Correlation between visual acuity and cognitive functions. Br J Ophthalmol. 2014; 98(1):129–32.
6. Gussekloo J, de Craen AJ, Oduber C, et al. Sensory impairment and cognitive functioning in oldest-old subjects: the Leiden 85+ Study. Am J Geriatr Psychiatry. 2005; 13(9):781–6.
7. Reyes-Ortiz CA, Kuo YF, DiNuzzo AR, et al. Near vision impairment predicts cognitive decline: data from the Hispanic Established Populations for Epidemiologic Studies of the Elderly. J Am Geriatr Soc. 2005; 53(4):681–6.
8. Rogers MA, Langa KM. Untreated poor vision: a contributing factor to late-life dementia. Am J Epidemiol. 2010; 171(6):728–35.
9. Crews JE, Campbell VA. Vision impairment and hearing loss among community-dwelling older Americans: implications for health and functioning. Am J Public Health. 2004; 94(5):823–9.
10. Hayman KJ, Kerse NM, La Grow SJ, et al. Depression in older people: visual impairment and subjective ratings of health. Optom Vis Sci. 2007; 84(11):1024–30.
11. Wahl HW, Heyl V, Drapaniotis PM, et al. Severe vision and hearing impairment and successful aging: a multidimensional view. Gerontologist. 2013; 53(6):950–62.
12. Dyall L, Kepa M, Hayman K, et al. Engagement and recruitment of Maori and non-Maori people of advanced age to LiLACS NZ. Aust N Z J Public Health. 2013; 37(2):124–31.
13. Hayman KJ, Kerse N, Dyall L, et al. Life and living in advanced age: a cohort study in New Zealand--e Puawaitanga o Nga Tapuwae Kia Ora Tonu, LiLACS NZ: study protocol. BMC Geriatr. 2012; 12:33.
14. Kerse N, Teh R, Moyes SA, et al. Cohort Profile: Te Puawaitanga o Nga Tapuwae Kia Ora Tonu, Life and Living in Advanced Age: a Cohort Study in New Zealand (LiLACS NZ). Int J Epidemiol. 2015; 44(6):1823–32.
15. Teng EL, Chui HC. The Modified Mini-Mental State (3MS) examination. J Clin Psychiatry. 1987; 48(8):314–8.
16. Busse A, Sonntag A, Bischkopf J, et al. Adaptation of dementia screening for vision-impaired older persons: administration of the Mini-Mental State Examination (MMSE). J Clin Epidemiol. 2002; 55(9):909–15.
17. Westheimer G. Scaling of visual acuity measurements. Arch Ophthalmol. 1979; 97(2):327–30.
18. The Cognitive Function and Ageing Studies: Baseline or Prevalence Screen 1989 United Kindom: Cambridge University. 1989.
19. Salmond C, Crampton P, Atkinson J. NZDep2006 Index of Deprivation. Department of Public Health, University of Otago. Wellington: Ministry of Health. Department of Public Health UoOWMoH; 2007.
20. Essink-Bot ML, Krabbe PF, Bonsel GJ, Aaronson NK. An empirical comparison of four generic health status measures. The Nottingham Health Profile, the Medical Outcomes Study 36-item Short-Form Health Survey, the COOP/WONCA charts, and the EuroQol instrument. Med Care. 1997; 35(5):522–37.
21. de Craen AJ, Heeren TJ, Gussekloo J. Accuracy of the 15-item geriatric depression scale (GDS-15) in a community sample of the oldest old. Int J Geriatr Psychiatry. 2003; 18(1):63–6.
22. Teh R, Doughty R, Connolly M, et al. Agreement between self-reports and medical records of cardiovascular disease in octogenarians. J Clin Epidemiol. 2013; 66:1135–43.
23. Kline RB. Principles and Practice of Structural Equation Modeling, third edition. New York: Guildford Press; 2011.
24. Salmond C, Crampton P, Atkinson J. NZDep2006 Index of Deprivation. Department of Public Health, University of Otago: Ministry of Health. 2007.
25. Bland RC, Newman SC. Mild dementia or cognitive impairment: the Modified Mini-Mental State examination (3MS) as a screen for dementia. Can J Psychiatry. 2001; 46(6):506–10.
26. Colenbrander A, de Laey JJ. Vision requirements for driving safety. International Council of Ophtalmology (ICO). 2006.
27. Patterson C, Feightner J, Garcia A, MacKnight C. General risk factors for dementia: a systematic evidence review. Alzheimers Dement. 2007; 3(4):341–7.
28. Lindenberger U, Baltes PB. Sensory functioning and intelligence in old age: a strong connection. Psychol Aging. 1994; 9(3):339–55.

29. Fauth EB, Schwartz S, Tschanz JT, et al. Baseline Disability in Activities of Daily Living Predicts Dementia Risk Even After Controlling for Baseline Global Cognitive Ability and Depressive Symptoms. Int J Geriatr Psychiatry. 2013; 28(6):597–606.

30. Sauvaget C, Yamada M, Fujiwara S, et al. Dementia as a predictor of functional disability: a four-year follow-up study. Gerontology. 2002; 48(4):226–33.

31. Tay T, Wang JJ, Kifley A, et al. Sensory and cognitive association in older persons: findings from an older Australian population. Gerontology. 2006; 52(6):386–94.

32. Hong T, Mitchell P, Burlutsky G, et al. Visual Impairment, Hearing Loss and Cognitive Function in an Older Population: Longitudinal Findings from the Blue Mountains Eye Study. PLoS One. 2016; 11(1):e0147646.

33. Valentijn SA, van Boxtel MP, van Hooren SA, et al. Change in sensory functioning predicts change in cognitive functioning: results from a 6-year follow-up in the Maastricht Aging Study. J Am Geriatr Soc. 2005; 53(3):374–80.

34. Salmond C, Crampton P, Atkinson J. NZDep2006 Index of Deprivation. Department of Public Health, University of Otago: Ministry of Health. 2007.