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Correlation between visual acuity and cognitive functions

Sivan M Elyashiv, Esther L Shabtai, and Michael Belkin

Sackler Faculty of Medicine, Goldschleger Eye Institute, Sheba Medical Center, Tel Aviv University, Tel Hashomer, Israel

Abstract

A possible association between visual acuity (VA) and dementia was investigated in 2716 subjects who were aged between 53 and 102 at first visit and had varying degrees of dementia. Better VA was found to be significantly correlated with a lower dementia level (person coefficient range 0.146–0.261 over 10 years of follow-up, all correlations are significant, $p < 0.0001$) as well as with a higher global cognitive score (person coefficient range -0.254 to -0.318 over 10 years of follow-up, all correlations are significant, $p < 0.0001$), a grade encompassing 19 different cognitive tests. This correlation remained significant after adjustment for age, years of education, gender, use of ophthalmic drugs and years of follow-up.

Visual and cognitive impairments are common causes of disability worldwide and contribute profoundly both to personal distress and to the burden on care providers. The prevalence of these impairments is increasing rapidly with the ageing of the population.¹ Previous studies have reported a possible association between visual disturbances and cognitive decline. Attempts to establish such an association are fraught with methodological issues, including the fact that cognitive functions are often measured by tests such as the Mini Mental State Examination (MMSE), the results of which may be skewed by impaired vision. While some studies have demonstrated that visually impaired subjects score lower on tasks that are not necessarily vision dependent,² others have related lower cognitive scores only to difficulty in completion of the test.³ Yet other studies have excluded visually impaired individuals as being ‘non-testable’, perhaps overlooking the possibility that this population may have a higher rate of dementia.

On the other hand, some studies have pointed to a strong association between cognitive and visual decline. In one retrospective study, untreated poor vision was found to be associated

Corresponding author: Dr Sivan M Elyashiv, Sackler Faculty of Medicine, Goldschleger Eye Institute, Sheba Medical Center, Tel Hashomer 52621, Israel; Sivanelya@gmail.com.

Contributors

As the corresponding author, I hereby certify that each author has participated sufficiently in the intellectual content and the writing of the work to take public responsibility for it. I also confirm that neither of the authors have any relationships/conditions/circumstances that present potential competing interests. Sivan Elyashiv, MD.

Competing interests

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with a ninefold risk of developing Alzheimer's disease (AD) and a fivefold risk of developing cognitive impairment with no dementia.⁴ Vision impairment predicting cognitive and functional decline was also demonstrated in a cohort of older women aged 69 or older.⁵

A number of ocular pathologies have been specifically associated with reduced cognitive functions. Besides the fact that age is a main risk factor for both AD and age-related macular degeneration (AMD), these two conditions share several characteristics. Deposition of extracellular β -amyloid is seen both in the senile plaques of AD and in the drusen of AMD, and complement system components have been implicated in both disease processes.⁶

In its 16th report, the Age-Related Eye Disease Study group noted that even after adjustment for several possible confounding factors, mean scores of cognitive function measured by tests in its Cognitive Function Battery declined significantly with increased macular abnormalities and reduced visual acuity (VA).⁷ A smaller study, conducted in Korea, compared the global cognitive scores (GCSs) of elderly patients with and without AMD. VA was found to be significantly correlated with cognitive global function in patients with mild cognitive impairment as reflected by the MMSE score, more distinctly so in AMD patients. The subgroup of 'geographic atrophy' was associated with the worst cognitive function.⁸

In other studies, it was shown that cognitive impairment may be common in patients with glaucoma.⁹ Visual field defects compatible with a diagnosis of glaucoma were found to occur at a higher rate in elderly patients with AD in Europe¹⁰ and in Japan.¹¹ Anatomical and histological similarities in thinning of the retinal nerve fibre layer and in retinal ganglion cell damage were observed both in AD and glaucoma.^{12,13} It is still a matter of debate, however, whether the association between reduced vision and cognitive decline signifies a common pathophysiological mechanism and whether a lack of sensory input contributes to the neurodegenerative process of AD.

Several studies have shown that treating visual impairment by cataract surgery improves cognitive function scores.^{14,15} An expansion of grey matter volume in the visual cortex was seen 6 weeks after cataract surgery, pointing to the possibility of cortical plasticity following visual improvement in adults.¹⁶

In the present study, we attempted to gain a better understanding of the possible association between vision impairment and cognitive function by analysing one of the largest used databases of elderly subjects suffering from various degrees of dementia and undergoing follow-up over a relatively long period.

SUBJECTS AND METHODS

The Religious Orders Study based at Rush University Medical Center in Chicago, Illinois, is a longitudinal clinical-pathologic cohort study of ageing and AD in a population of 1100 older Catholic nuns, priests and brothers who undergo annual medical and psychological evaluations and have agreed to donate their brains to science after death.¹⁷ The Memory and Aging Project at Washington University School of Medicine and Barnes-Jewish Hospital is a long-term epidemiologic clinical-pathologic study of cognitive functioning in more than 1200 ageing individuals from a range of backgrounds who undergo annual clinical

evaluations and have agreed to donation of brain, spinal cord and muscle after death. For purposes of the present study, we extracted data accumulated over a follow-up period of approximately 18 years between 1994 and 2013 from the records of a total of 2716 subjects from the two studies. All of the study participants were aged between 53 and 102 at first visit.

Demographic data (race, gender and years of education), as well as cognitive data and data pertaining to VA, had been recorded at baseline (see tables 1 and 2). Thereafter, follow-up data on cognitive status and VA were recorded annually. Cognitive function was measured by a GCS, a summary of raw scores of 19 different tests estimating episodic memory, semantic memory, working memory, perceptual speed, neuropsychological screening and visuospatial ability.¹⁸ Scores were converted to standard scores, averaged and normalised. Each year, an estimated clinical diagnosis score termed the dementia level was awarded on a categorical scale over the five categories of ‘no cognitive impairment’, ‘mild cognitive impairment’, ‘mild cognitive impairment and other diagnoses’, ‘Alzheimer’s disease’ and ‘Alzheimer’s disease and other diagnoses’. Subjects who obtained an assessment in one of the ‘other diagnoses’ categories were excluded from analysis in order to avoid diagnoses with aetiologies common to both visual impairment and cognitive decline, such as cerebrovascular accident.

VA was tested with both eyes open. A card was held at a distance of 14 inches and measured at seven increments ranging from 20/40 or better (arbitrarily categorised as -1) to 20/400 or worse (categorised as -7).

The use of ophthalmic drops (including artificial tears and antiglaucoma and anti-inflammatory agents) was recorded, but no categorical distinction was made with regard to medication group.

Statistical methods

Pearson and Spearman correlation coefficients were used, as applicable, to assess relationships among severity of dementia, GCS and VA. These indices were calculated separately in each year of follow-up.

The GCS values obtained by patients treated with ophthalmic preparations and by untreated patients were compared by the use of Student t test, and their dementia levels were compared using the non-parametric Mann–Whitney test.

ANOVA with repeated measures (time points) was used to examine the effects of VA, age, years of education, gender, use of ophthalmic drugs and years of follow-up on the GCS. A mixed model was chosen for this analysis in order to account for the hierarchical structure of the data, time-dependent covariates and missing values.

All statistical analyses were performed using SAS for Windows V.9.3.

RESULTS

A total of 2716 subject records were reviewed (1940 women, 776 men). The mean age of subjects at the beginning of follow-up was 78 (range 53–102).

Racial distribution was 92% white and 7% African-American. The remaining 1% was composed of Native Americans and Asians. The average number of years of education was 16 (15.6 years for women and 16.8 for men). The mean follow-up time was 4.4 years (range 0–18 years), and the mean number of visits was 6.5 (range 1–19).

At the first visit (baseline), 68.55% of subjects had no cognitive impairment, 25% had mild cognitive impairment and 5.5% had been diagnosed with AD. The average GCS was 0.00636. At the same time, VA of at least 20/40 was obtained by 74% of the subjects, 20/50 by 12% and 20/400 by only 2.6%.

Approximately one-half (51%), that is, 1122 of the subjects had ‘no cognitive decline’ at baseline, but were found to have progressed to some form of dementia during follow-up. Whereas only 124 of the subjects (4.5%) already had AD at the first visit, during follow-up 651 more subjects (23.95%) were diagnosed with AD (see table 3).

Subjects who had ‘no cognitive decline’ at baseline had a mean VA of 1.4 (median of 1, corresponding to a VA of 20/40 or better), whereas subjects diagnosed with AD had a mean VA of 2.27 (also with a median of 1).

Changes in severity of VA, GCS and dementia over time are recorded in figure 1.

Pearson correlation coefficient was calculated in each year of follow-up and demonstrated a low but significant correlation between VA and level of dementia. The trend is depicted in figure 2.

The correlation was strongest during the first 3 years of follow-up years. It then remained stable until the 7th follow-up year and weakened thereafter.

Similarly, better baseline VA was significantly associated with a lower level of dementia and a higher GCS at the end of follow-up.

ANOVA with repeated measures using the mixed model (shown in table 4) was used to assess the relationship between GCS levels and parameters such as VA, age at first visit, years of education and gender. The main result, when adjusted for age at first visit, number of years of education, gender and length of follow-up, was a significant positive correlation between VA and GCS (better VA with better GCS).

Each of the secondary parameters (listed in table 4) was also significantly correlated with GCS. A higher (better) GCS was correlated with younger age, shorter follow-up, female gender and more years of education. There was no correlation between GCS and the use of ophthalmic drugs.

Because of the high dropout rate after the first 10 years, the full cohort analysis was repeated twice, once for subjects with at least 4 years of follow-up and once for subjects who were followed up for at least 10 years. Similar results were obtained in each case.

DISCUSSION

As the fastest growing population sector in most countries is said to be the oldest old (>85 years of age),¹⁹ dealing with the consequences of longevity takes on a growing importance. One consequence is dementia, the prevalence of which according to a US population-based study increases with age from 5.0% at the age of 71–79 to 37.4% of those aged 90 and older.²⁰

An association between visual impairment and cognitive decline has been previously described in a number of studies⁴⁵²¹ but up to now has not yet been characterised. The fact that both pathologies become more prevalent with older age raises the possibility that they share some common pathophysiological aspects, and thus that one may lead to the other.

The present large cohort study incorporates a follow-up of up to 18 years in an elderly population with various levels of cognitive function. We found an interrelationship between VA, dementia level and GCS, regardless of whether the analyses were conducted in terms of a single variable or in the context of age, gender or education. Moreover, the correlation was consistent whether applied to the entire cohort or as a subanalysis of subjects with at least a 4-year or a 10-year period of follow-up. The correlation coefficient was low, reflecting the fact that dementia is a multifactorial entity. Various pathophysiological, environmental and behavioural factors have previously been associated with the occurrence and natural history of cognitive decline.^{22–25}

In contrast to some reports that the role of sensory function increases in importance with advancing age and may explain most differences in intelligence among the very old,²⁶²⁷ we found the correlation between VA and cognitive function to be stronger at earlier stages of follow-up and to show a slight decrease over time. This observation may have two possible explanations. One is the increased variability of cognitive function with advancing age, as previously described.²⁸²⁹ The other is an increasing role of factors other than vision that contribute to cognitive decline in older age.

The strength of this study derives from its very large population and long follow-up. However, it also has several limitations:

1. VA was measured in large increments that are not consistent with the LogMAR scale.
2. There is a potential for decreased VA to adversely affect the ability of some individuals to complete certain tasks used in neuropsychological testing.
3. Although a long follow-up period was noted for some subjects, there was a substantial dropout after the 7th year and the average follow-up was 4.48 years.
4. Where visual impairment was present, its aetiology was not recorded.

Lack of optimal correction of VA is very common among the elderly and this lack is a major cause of limitation of activities of daily living in this population.³⁰ As visual impairment in most cases is treatable, at least to some extent, and since visual rehabilitation has been shown to improve several aspects of cognitive function even in elders with low vision,³¹ it is imperative to further validate and define the association of visual impairment and cognitive decline.

Our findings might become more useful if the ability to predict visual deterioration in the elderly is substantiated.³² This study, given its large cohort, further establishes this association and discloses its relevance at an earlier point than previously thought. An interesting possible implication is that early intervention towards vision correction may reduce the severity of dementia and its associated functional decline.

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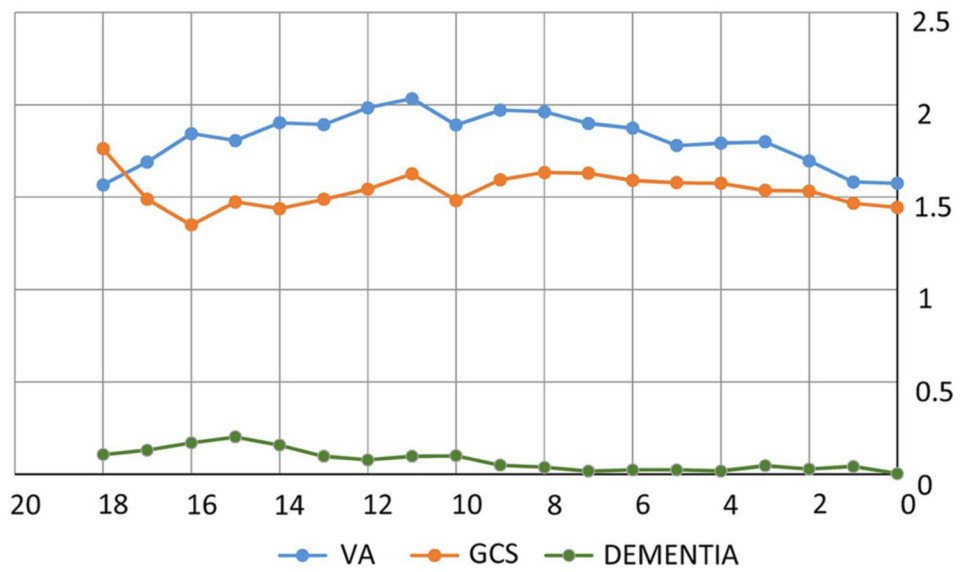


Figure 1. Changes in visual acuity (VA), global cognitive score (GCS) and dementia over 18 years of follow-up. Access the article online to view this figure in colour.

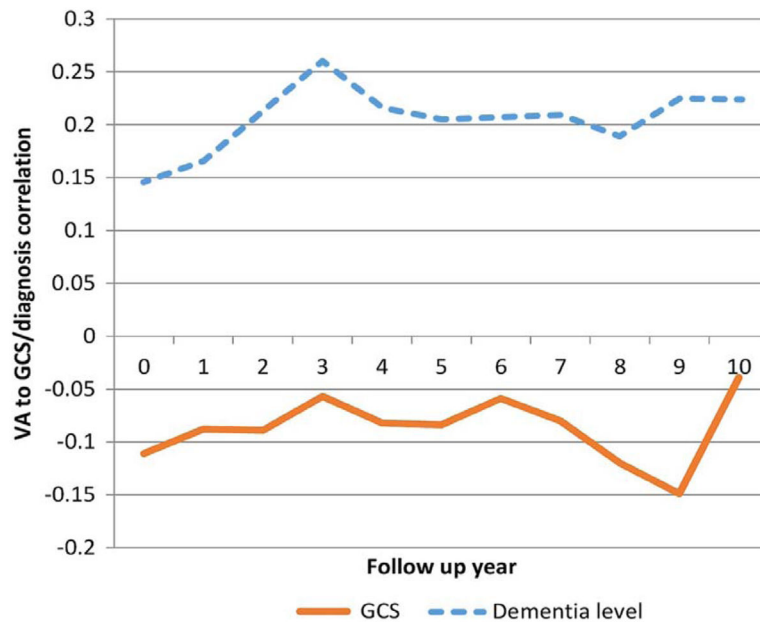


Figure 2. Correlation between visual acuity (VA) and dementia level (global cognitive score (GCS)) over 10 years of follow-up. The GCS shows a negative correlation with VA because a higher VA score (as arbitrarily determined in this study) signifies a lower VA. This relationship is maintained during the first 7 follow-up years, as higher VA can be seen to be correlated with better (higher) GCS. Access the article online to view this figure in colour.

Table 1

Patient demographics and baseline characteristics

	N	Mean	SD	Median	Minimum	Maximum
Age	2718	78.13	7.86	78.92	53.35	102.15
Years of education	2716	16.01	3.77	16.00	0.00	30.00
Follow-up years	2718	0.02	0.30	0.00	0.00	10.00
Visual acuity	2718	1.58	1.30	1.00	1.00	7.00
Level of dementia	2715	1.44	0.80	1.00	1.00	5.00
Global score	2718	-0.00	0.64	0.10	-3.99	1.46

Table 2

Patient baseline characteristics

	N	%
Gender		
Women	1940	71.43
Men	776	28.57
Visual acuity		
1	2018	74.25
2	346	12.73
3	137	5.04
4	83	3.05
5	30	1.10
6	32	1.18
7	72	2.65
Ophthalmic drugs		
No	2236	82.27
Yes	482	17.73
Level of dementia		
1	1861	68.55
2	682	25.12
3	11	0.41
4	150	5.52
5	11	0.41

Table 3

Dementia levels at first follow-up and last follow-up

Dementia level	At first follow-up		At last follow-up	
	Number	Per cent	Number	Per cent
1	2203	81.05	1081	39.77
2	381	14.02	961	35.36
3	10	0.37	25	0.92
4	117	4.30	582	21.41
5	7	0.26	69	2.54

Table 4

Mixed model analysis for associations with global cognitive score

Effect	Estimate	SE	Pr> t
Visual acuity	-0.03312	0.002021	<0.0001
Age at baseline	-0.03897	0.001614	<0.0001
Years of education	0.04537	0.003354	<0.0001
Women	0.1209	0.02734	<0.0001
Years of follow-up	-0.04553	0.001789	<0.0001
Ophthalmic drops	0.01016	0.007030	0.1489