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Visual search contributes to subjective judgment of visual efficiency in older adults

Introduction: The determinant factors that influence self-reported quality of vision have yet to be fully elucidated. This study evaluated a range of contextual information, established psychophysical tests, and in particular, a series of cognitive tests as potentially determinant factors. Materials & Methods: Community dwelling adults (aged 50+) recruited to Wave 1 of The Irish Longitudinal Study on Ageing, excluding those registered blind, participated in this study (N=5021). Self-reports of vision were analysed in relation to visual acuity and contrast sensitivity, ocular pathology, visual (Choice Response Time task; Trail Making Test) and global cognition. Contextual factors such as having visited an optometrist and wearing glasses were also considered. Ordinal logistic regression was used to determine univariate and multivariate associations. Results and Discussion: Visual acuity (Odds ratio (OR) =1.71), ocular pathology (cataract, OR=1.78; glaucoma, OR=2.43; ARMD, OR=3.48; other pathologies, OR=2.83), lack of correction (glasses, OR=1.34), poor visual cognition (Trail Making Test, OR= 1.35) were determinant factors for poor versus excellent vision in self-reports. Education, wealth, age, depressive symptoms and general cognitive fitness also contributed to determining self-reported vision. Conclusions: Ocular pathology underlies the presence of visual deficits that are not fully captured by the acuity test. Poor visual search and visual attention skills capture the functional use of vision linked to higher level visual processing. Age, education and wealth, as well as mental health also bias responses. A careful examination of the respective contribution of such factors should be considered when using self-reports to asses vision and its role in cognitive and functional health.

Visual search contributes to subjective judgment of visual efficiency in older adults

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Introduction

Many subjective psychological constructs have been shown to have a number of objective underlying determining factors, self reported memory is a clear example, in so much that is has been argued that other psychological aspects such as depression and personality could be more linked to self reports of memory than memory itself (Abdulrab & Heun 2008). In the present work we analyzed another psychological construct, self reported vision and investigate the contribution of cognitive factors to this construct in a large sample of individuals aged 50 and over. Although it is clear that the answer to one simple question on one's own visual ability can be largely dependent on factors other than visual acuity, the specific aim here is to contribute in shedding light on whether higher level visual processing (e.g. visual search) can independently contribute to the subjective awareness of visual deficits. Whether impairment in visual cognition independently from wider cognitive impairments and lower level acuity impairment can be captured by subjective reports of poor vision remains to be determined and could contribute in explaining why some individuals with good acuity report poorer vision and vice versa. In the domain of hearing extensive work has been devoted to central presbycusis showing that specific hearing deficit linked to central hearing processing may exist independently both from peripheral deficits and central cognitive deficits and can be captured in the subjective experience of individuals with poor hearing (Humes et al. 2012). With ageing the relationship between sensory efficiency and cognitive performance becomes closer (Lindenberger & Baltes 1994; Lindenberger & Ghisletta 2009) and self reports of vision are predictive in terms of negative cognitive outcomes (Rogers & Langa 2010). While it is established that visual acuity is not the only determinant of self reported vision (Rubin et al. 2001), it is necessary to understand what are the factors underlying it. Among these factors arguably the least investigated is the cognitive dimension, while greater emphasis has been given to objective visual measures such as visual acuity (Klein et al. 1999; Rubin et al. 2001), use of vision to accomplish daily tasks (e.g Fors et al.

2006; Kempen et al. 1996; Rubin et al. 2001; Rubin et al. 2007), and as socio-demographic factors (El-Gasim et al. 2012; Klein et al. 1999; Rubin et al. 2001). In fact while self reports are widely used in epidemiological studies little research has been devoted to cognitive factors. Further our understanding of these factors could inform the use of self reports in clinical settings where knowing the validity of a simple question could inform on the need for further assessments that go beyond a visual acuity test.

The aim of the present work is to establish the cognitive contribution to self reports of vision focusing on two aspects: the general contribution of global cognition to self reports and the specific contribution of visual cognition. Here we consider visual cognition as visual processing deficits that are not detected by visual acuity tests can play a relevant role in the functional use of vision and therefore contribute to self reports.

Previous studies have investigated intelligence (Kempen et al. 1996) and global cognitive status (Hidalgo et al. 2009) but their results are limited by the impossibility to control for a range of confounding factors.

As to the role of visual cognition this has not been studied in relation to SRV at a population level. Measures of visual processing differ from traditional psychophysical measures such as visual acuity, particularly in relation to the balance of influence of optical (Owsley 2011) versus neural factors (Faubert 2002) in the determination of functional performance level. Modifications occurring in the visual cortex, as well as more generally in the functional organisation of visual processing, could, therefore, be responsible for age related changes in visual function (Cabeza et al. 1997; Grady 2008) and potentially be captured by self-reports. In fact, one of the most notable changes in cognitive ageing is the decline in visual processing speed that is also a marker of cognitive decline (Salthouse 1996; Salthouse et al. 1996). Visual search is also one of the domains of visual processing that deteriorates with ageing in a manner that relates to visual attention decline (Madden 2007).

The natural decline in visual processing has a number of consequences on the ability to perform daily living tasks such as navigating the environment (including the possibility of suffering a fall), Anstey et al. (2009) looking for a particular object or a person among others (Sekuler & Ball 1986) and driving (Ball et al. 2006). These processes also mediate the successful training of visual capacities to improve daily living activities (Ball et al. 2007; Edwards et al. 2012) and could, therefore, impact self perceived quality of vision. In the present study visual search and attention are assessed by the Trail Making Test, a commonly used neurocognitive test (D'Elia et al. 1996). This test was selected on the basis that visual search, scanning and visual attention are engaged in this task (Sanchez-Cubillo et al. 2009). The visual processing speed is measured using a specifically devised task based on the vast literature on processing speed tasks.

A number of other factors need to be controlled for that may determine SRV: eye disease, common in older adults, and can result in substantial visual loss not captured by a visual acuity tests (Charalampidou et al. 2011); the awareness of a visual problem could potentially be linked to the frequency of attendance for eye health examination, which should be accounted for. In addition socio-demographic and general physical and mental health factors should be accounted for.

Materials & Methods

Sample

Data from the first wave of the nationally representative Irish Longitudinal Study on Ageing (TILDA), were used for this study (N=8175 aged 50 years and older). The recruitment and sampling method has been described elsewhere (Kearney et al. 2011). Ethical approval was obtained from the Trinity College Dublin research ethics committee, and all participants provided written informed consent in accordance with the Declaration of Helsinki.

All participants completed a Computer Assisted Personal Interview (CAPI) in their own home, and each was then invited to a complete a health assessment (Kearney et al. 2011). For the purpose of this study, only participants who attended the health assessment centre are included (N = 5026; 2304 male). Those respondents who reported themselves as registered blind [legally defined as visual acuity less than LogMAR 1.0 (6/60) or visual field less than 20º] were also excluded from all the analyses (N=5, 0.1% of the sample). The total sample size, therefore, included in the current study was N=5021 (2299 male).

Outcome variable:

SRV was assessed during the CAPI with the following question: "Is your eyesight (using glasses or contact lenses if you need them) ... excellent, very good, good, fair, poor, registered blind". Those who reported themselves as 'registered blind' were not included in the study yielding a five point ordered scale for SRV.

Predictor variables:

Global cognitive status

Global cognitive status was assessed by the Montreal Cognitive Assessment, (MoCA), a widely used neurocognitive assessment. For the purpose of the present work we excluded the visual items to avoid a bias poor vision onto the overall cognitive assessment.

Visual cognitive processing

Choice Reaction Time (CRT) test: the CRT is a computer based test, and was administered at the health assessment according to a Standard Operating Procedure. The task consisted of three phases: maintaining the starting button press; releasing the button at the appearance of the target stimulus (words "yes" or "no") on the computer screen (cognitive speed), and finally, pressing the button corresponding to "yes" or "no" on the button-box (motor speed).

Visual search

The Trail Making Test (TMT) was used to test visual search skills. The TMT is administered in two versions, the first is simpler, requiring to draw a line between consecutive numbers distributed on a sheet of paper (TMT1), and the second is more complex, requiring to alternate between numbers of two different colours (TMT2). This test, administered during the Health Assessment following a Standard Operating Procedure, was presented in the colour version; Before each of the TMTs, respondents were allowed a short practice run. The total time to perform the TMT (1 and 2) task, as recorded by the nurse, was used for the current study.

Vision related covariates

Visual acuity was measured monocularly during the health assessment using a LogMAR chart, and ETDRS letterset, at a test distance of four meters under photopic illumination conditions. Subjects were required, using their habitual refractive correction where applicable, to identify the letters presented on the chart in decreasing size (0.1 log unit decrease in size between lines). Visual acuity was recorded as the smallest line of letters accurately identified, accounting for any incorrectly identified letters on this line (each line consisted of five letters, each assigned a value of 0.02 log units, such that if a subject, for example, correctly identified four letters of the LogMAR 0.1 line, and incorrectly identified one letter, the final acuity was recorded as 0.12). For the present study visual acuity in the best performing eye was considered.

Contrast sensitivity (CS) was measured monocularly, with distance spectacles worn (where appropriate), using the Functional Vision Analyser™ (FVA; Stereo Optical Co., Inc – Chicago, USA). For the methodology see (Loughman et al. 2012). Testing was performed under mesopic (3 cd/m2) background illumination conditions.

Eye disease and contextual variables

During the CAPI interview, respondents were asked to indicate the nature of any existing doctor-confirmed diagnosis of eye disease. Subjects were additionally asked to provide information in relation to their habitual use of spectacles or contact lenses, and visits to an optometrist.

Other covariates

Other covariates considered in this study were: age, sex, education, health (chronic conditions), wealth (based on house value), all of which were self-reported; hypertension (seating position systolic blood pressure > 140 ml mercury or diastolic > 90 ml mercury) and depression (Centre for Epidemiological Studies Depression Scale (CES-D), all of which were measured during the health centre visit.

Statistical Analysis

Ordinal logistic regression was used to investigate the association between the variables of interest (visual acuity, contrast sensitivity, report of eye disease, wearing glasses, having visited an optometrist, CRT and TMT) and the outcome variable (self-report of vision on a five point Likert scale). Ordinal logistic regression yields odds ratios that can be interpreted in the same way as for binary logistic regression, but irrespective of the dichotomization of the outcome variable. The 'proportional odds' assumption is therefore key, this is the assumption that OR's generated by the ordinal regression are applicable across the whole of the response range of the outcome. Each of our variables of interest passed a 'Brant' test for proportional odds (R 1990) (using the 'brant' command in Stata) and so this assumption was met. Univariate odds ratios were estimated for each predictor, as well as odds ratios adjusted for all covariates and other predictors.

Inverse probability weights were estimated and applied to all analyses to ensure that results based on the sample included in the current analysis were applicable to the community

living middle aged and older population of Ireland. Statistical analyses were performed using STATA version 12 (StataCorp LP, College Station, TX).

Results & Discussion

Using the legal (visual acuity based) definition of visual impairment (corrected visual acuity < 20/40 or > 0.3 LogMar) as a proxy indicator of good (equal or better than 0.3) versus poor (worse than 0.3) visual acuity, 89.8% of participants who reported good vision (excellent to good) had good visual acuity, while the remaining 10.2% demonstrated poor visual acuity. Among respondents rating their vision as poor, only 22.4% showed impaired visual acuity.

Considering the exclusion of participants presenting missing values on at least one of the variables of interest or covariates, the total sample entered into the final model was N = 4178 (1937 male), of which, 292 individuals (7%) reported fair or poor vision.

The descriptive statistics of the sample are presented in Table 1.

Table 1

The odd ratios for the association between each predictor variable and poor SRV are shown in Table 2.

Table 2

Cognitive function measured by MoCA (with visual elements removed) retained a small statistically significant effect on SRV indicating a contribution of general cognitive function even after adjusting for all other covariates (OR=0.97 per point; p=0.04).

There was initial evidence that poor processing speed as measured by CRT independently influenced SRV, but this was not statistically significant (O.R.=1.21; p > 0.05 for poorest compared to best quintile). There was a dose-response relationship between slow-

visual search (measured by TMT) and SRV in univariate analysis. After adjusting for all other factors, those participants with visual search times in the slowest quintile had poorer SRV (OR=1.35; p=0.02). It is worth noting that the question on SRV was answered a few weeks before the health assessment, carry-on effects from the cognitive tasks to the self-reports can, therefore, be excluded.

Among vision related covariates, as expected there was a gradient in SRV with worsening visual acuity, with odds ratio of 1.71 for lowest quintile (corresponding to LogMar mean = .345, standard deviation = .153) compared to the highest quintile (LogMar mean -.131, standard deviation = .054). The univariate effect of low-frequency CS (OR=3.1; p<0.01 for poorest compared to highest quintile) was almost completely explained by confounding factors. High frequency CS was not related to SRV independently of visual function. Eye disease was associated with self reporting poor vision, Cataract (OR=1.78, p=0.001), Glaucoma (OR=2.43, p=0.001), Age Related Macular Degeneration (OR=3.84, p=0.01) and other ocular pathologies (not qualified) (OR=2.83, p=0.001) were all significant determinants of self reported vision. Independently of all other factors, not wearing glasses had a small but significant impact in increasing the odds of poor SRV (OR=1.34; p<0.01).

As to the other covariates, age, education and wealth were significant determinants of the self reports. Mental health had a highly significant impact on the ratings, with a dose response pattern indicating that more depressed participants were more likely to rate their vision as poorer. To clarify whether the relationship of TMT with SRV performance could be attributed to visual search skills in this context, additional analyses were performed. Adding individual MoCA subscores to the model relating to working memory (serial subtraction), executive function (verbal fluency), which have been associated with TMT performance, (Crowe 1998) or visual reasoning (indicative of fluid intelligence) (Salthouse 2011) did not attenuate the effect of TMT on SRV (data not shown).

Limiting the sample to participants who wore glasses during the health assessment (N= 3302) had no substantial impact on the pattern of results (data not shown).

The prevalence of sub-optimal self reported visual function (identifiable in 'fair' and 'poor' vision) is relatively low (7%). However this is in line with existing literature, for example reported a prevalence of self reported fair and poor vision of 10% in people aged between 40 and 69 was reported (Klein et al. 1999), while the prevalence increased over 70 years of age. Hidalgo et al. (2009) report a prevalence of 6% (bad or very bad vision by self report) in participants age 65 and older. Although the current study confirms a relationship between visual acuity and SRV, additional factors including the presence of ocular pathology and reduced visual processing capacity are identified as important determinants of SRV.

Visual cognition was associated with SRV, in particular TMT was associated with SRV independent of global cognition. The lack of significance of the CRT in the fully adjusted model is to be expected, in consideration of the fact that processing speed for visual targets is also captured by the TMT. The association between slow TMT and poor SRV may indicate that the TMT captures the contribution of visual search and visual attention (Crowe 1998; Salthouse 2011; Sanchez-Cubillo et al. 2009) to SRV. Indeed TMT has been used previously as a measure of visual scanning to predict driving restriction or cessation in line with other visual attention tasks (Keay et al. 2009).

Cognitive status, assessed by the MoCA indicated that higher cognitive scores were associated with decreased likelihood of self reporting poor vision. This result could be interpreted in terms of coping strategies. It is plausible to assume that memory and attention could contribute in maintaining functional efficiency in spite of a visual acuity deficit. It has been indicated previously, that the Short Portable Mental Status Questionnaire score (dichotomized according impairment and no impairment), which assesses global cognition,

was associated with the score obtained in the Visual Function Index questionnaire (VF-14) (Hidalgo et al. 2009).

As expected, visual acuity and (self reported) ocular pathologies, independent of VA and CS, were associated with a substantial increase in the likelihood of reporting poor vision. The increased level of association suggests that self-reports capture day to day visual deficits that are not fully captured by acuity measures (Charalampidou et al. 2011; Tejeria et al. 2002).

The contribution of wearing glasses to self-reports could be due to a need for refractive correction, whereby respondents not wearing glasses may need to correct a deficit that is not entirely captured by the distance visual acuity test, for example, for near vision.

Among the non vision-related covariates, the protective effect of age is notable, with older olds (65+) reporting relatively better vision than younger olds (50-54) even if acuity was controlled for. This may suggest a positive bias in self reports with ageing. Alternatively it may indicate that older people have developed coping strategies that alleviate the impact of their visual deficits on their daily life.

Higher educated individuals and wealthier individuals were also more likely to report good vision. This may be due to a positive attitude in self reports. However at present it is not possible to exclude that both self reported health and quality of life may be related to better coping strategies developed by more educated and wealthier individuals. The effect of depression can plausibly be attributed to a general tendency of depressed individuals to a pessimistic view on their health.

Conclusions

Our results confirm the existing evidence that visual acuity is a clear contributor to SRV as well as ocular pathology. More importantly in relation to our hypotheses, higher level visual processing, in terms of response time to visual stimuli (CRT/TMT) and time to perform

a visual search (TMT) play a part in SRV. This may be due to visual deficits linked to higher level visual processing that are not fully captured by psychophysical tests. A limitation of this study is that TMT is not the 'purest' instrument to test the contribution of higher level visual processing to SRV because of the variety of cognitive processes involved in performing it (Crowe 1998; Salthouse 2011; Sanchez-Cubillo et al. 2009). However it represents a viable instrument in the context of this epidemiological study.

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Table 1. Characteristics of the Sample (N=4178 Weighted to Represent the Population)

Variable+	Excellent vision (N=903)	Very good vision (N=1631)	Good vision (N=1352)	Fair vision (N=262)	Poor vision (N=30)	P value
Trail Making test 1	52.5 (50.7,54.3)	56.3 (54.7,57.9)	58.8 (57,60.5)	64 (60,68)	89.3 (72.4,106.2)	<.001
Trail making test 2	105.2 (101.7,108.6)	111.1 (108.5,113.7)	116.9(113.7,120.1)	129.8 (121.7,138)	163.6 (138,189.5)	<.001
CRT total time (ms)	787.2 (767.2,807.1)	824 (806.6,841.4)	836.3 (817.4, 855.2)	904.1 (829.3, 979)	1016.7 (827.6,1205.9)	<.001
CRT cog time (ms)	522.8 (509.7, 535.8)	538.8 (528.7,548.9)	543.7 (533.8, 553.6)	582.7 (546.5, 618.9)	648.5 (545.8,751.2)	<.001
MoCA score (/30)	25.5 (25.2,25.7)	25 (24.8,25.2)	24.5 (24.3,24.8)	23.8 (23.3, 24.3)	21.8 (20.2,23.4)	<.001
Visual reasoning (/5)	3.2 (3.1,3.3)	3 (2.9,3.1)	2.9 (2.8,3)	2.9 (2.7,3.1)	2.7 (1.7,3.6)	< .001
Visual acuity (logMar)	.02 (.01,.04)	.06 (.05,.07)	.09 (.07,.1)	.12 (.1, .15)	.26 (.14,.37)	< .001
Contrast sensitivity low fq.	38.2 (36.6,39.8)	36.6 (35.5,37.7)	36.4 (35.17,37.73)	33.8 (31,36.7)	22.2 (14.4,30)	< .001
Contrast sensitivity	52.7 (50.9,54.5)	49. 6 (48, 51.1)	48.1 (46.5,49.7)	43.2 (39.5, 46.8)	28 (19.4,36.6)	< .001

middle fq.						
Contrast sensitivity high fq.	4.3 (3.9,4.7)	3.5 (3.2,3.9)	3.2 (2.9,3.5)	3.1 (1.6,4.6)	1.1 (-.06,2.3)	< .001
Ocular pathology (any) (%)	8.4 (6.2,11.3)	13.2 (11.1,15.5)	18.3 (1.6,21.3)	32.4 (25.7,40)	67.4 (46.5,83.2)	< .001
Cataract (%)	5.9 (4.1,8.6)	9 (7.2,11.2)	11.7 (9.4,14.5)	21.0 (14.9,28.9)	41.5 (20.7,65.9)	< .001
Glaucoma (%)	.6 (.3,1)	1.7 (1.13,2.6)	2.4 (1.7,3.6)	5.5 (2.8,10.5)	13.3 (3.2,41.8)	< .001
AMD (%)	.7 (.3,1.6)	.9 (.5,1.7)	1.9 (1.1,3.2)	3.7 (1.4,9.1)	17.7 (4.8,48)	< .001
Other (%)	1.2 (.7,2.2)	2 (1.28,3.02)	3.7 (2.8,4.8)	6.2 (3.79,9.8)	8.8 (2.78,24.7)	< .001
Wear glasses (%)	68.8 (64.6,72.6)	63.5 (60.1,66.7)	61.5 (57.6,65.3)	62.2 (55.2,68.7)	59.1 (35.3,79.3)	.177
Visited optometrist (%)	8.8 (6.6,11. 6)	13.9 (11.7,16.4)	13 (10.8,15.5)	19.1(13.21,26.7)	36.2 (17,61.2)	< .001
Wealth (rent or house value <400.000 €) (%)	76.2 (72.1,79.9)	83.8 (81.2,86.1)	87.3 (84.8,89.4)	90.6 (86.25,93.7)	90.2 (76.1,96.4)	< .001
Age (years)	61.4 (60.7,62.2)	62.8 (62.1,63.5)	63.1 (62.38,63.9)	63.3 (61.6,65.1)	69.4 (64.9,73.9)	< .001
Sex (male)	51.7 (48.2,55.3)	48.4 (45.8,51.1)	48.2 (45.2,51.2)	48.1 (40.9,55.4)	39.4 (21.3,60.9)	.5673

Education primary or none(%)	22.5 (19,26.4)	32.8 (29.8,36)	38.4 (34.9,42.1)	49.23 (42.1,56.4)	70.8 (52.3,84.2)	<.001
Hypertension++(%)	38.4 (34.7,42.2)	42.7 (39.8,45.8)	40.15 (37,43.4)	43.6 (36.3,51.1)	65.1 (43,82.2)	<.05
Stroke or TIA(%)	1.4 (.8,2.4)	2.2 (1.54,3.3)	4.9 (3.53,6.7)	6.1 (2.92,12.3)	4.8 (1.1,19.3)	<.01
Diabetes(%)	5.5 (3.9,7.8)	6.5 (5.1,8.1)	7.7 (6.1,9.7)	6.1 (3.5,10.2)	9.5 (3.2,25)	.53
Chronic conditions(%)	47.4 (43.6,51.1)	51.5 (48.6,54.4)	56.3 (53.1,59.4)	71.9 (65.4,77.6)	76.3 (58.3,88.1)	< .001
Hearing (poor) (%)	1.23 (.63,2.4)	1.1 (.66,1.8)	2.58 (1.8,3.7)	4.1 (2,8.2)	13.6 (3.6,40.2)	< .001
Depression (severe) (%)	6.1 (4.4,8.3)	7.9 (6.4,9.7)	9.5 (7.7,11.6)	17.3 (12.4,23.5)	27.7 (12.3,51.1)	< .001

+The P values refer to one-way ANOVA tests for means comparison or Chi-square tests for frequencies comparisons. Confidence intervals in parentheses.

++ All cardiovascular health measures are self-reported (CAPI interview) apart from Hypertension that is measured in the health assessment.

Table 2. Ordinal Odds Ratios Representing the Effect of Potential Contributing Factors to Self- reported Vision (Excellent, Very Good, Good, Fair, Poor)

	Univariate effect		Multivariate effect+	
	OR	95% CI	OR	95% CI
Visual acuity (best quintile)	1	[1.00,1.00]	1	[1.00,1.00]
2nd	1.60*	[1.01,2.56]	1.21	[1.00,1.47]
3rd	1.89**	[1.28,2.81]	1.30*	[1.06,1.60]
4th	3.13***	[2.10,4.66]	1.50***	[1.20,1.88]
Lowest quintile	4.02***	[2.70,5.99]	1.71***	[1.36,2.15]
High frequency CS (lowest quintile)	1	[1.00,1.00]	1	[1.00,1.00]
2nd	1.37	[0.93,2.02]	0.86	[0.69,1.06]
3rd	1.79**	[1.19,2.69]	1.07	[0.85,1.35]
4th	0.8	[0.52,1.22]	1.04	[0.84,1.28]
Highest quintile	0.83	[0.54,1.27]	1.03	[0.83,1.29]
Low frequency CS (lowest quintile)	3.09***	[2.03,4.71]	1.23	[0.97,1.55]

2nd	1.21	[0.76,1.95]	1.04	[0.85,1.28]
3rd	1.4	[0.92,2.12]	1	[0.81,1.23]
4th	1.13	[0.70,1.82]	0.99	[0.81,1.20]
Highest quintile	1	[1.00,1.00]	1	[1.00,1.00]
Cataract	1.99***	[1.62,2.44]	1.78***	[1.31,2.41]
Glaucoma	2.15***	[1.44,3.23]	2.43***	[1.50,3.93]
ARMD	3.91***	[2.38,6.44]	3.48**	[1.49,8.08]
Other eye pathology	2.94***	[2.11,4.10]	2.83***	[1.79,4.48]
Doesn't wear glasses	1.12	[0.86,1.47]	1.34***	[1.14,1.57]
Optician visit	1.73**	[1.20,2.49]	1.02	[0.81,1.28]
Choice reaction task time (fastest)	1	[1.00,1.00]	1	[1.00,1.00]
2nd	1.43	[0.92,2.22]	1.08	[0.89,1.30]
3rd	1.2	[0.76,1.90]	0.97	[0.80,1.18]
4th	1.56	[0.99,2.44]	1.08	[0.87,1.35]
Slowest quintile	3.00***	[1.91,4.71]	1.21	[0.95,1.54]

Trail making task time (best quintile)	1	[1.00,1.00]	1	[1.00,1.00]
2nd	0.96	[0.61,1.52]	1	[0.82,1.21]
3rd	1.19	[0.77,1.83]	1.03	[0.83,1.27]
4th	1.55*	[1.02,2.34]	1.09	[0.86,1.38]
5th quintile	3.16***	[2.11,4.71]	1.35*	[1.05,1.75]
MoCA score without visual elements (per point)	0.89***	[0.86,0.92]	0.97*	[0.95,1.00]
Female vs male	1.18	[0.91,1.54]	0.99	[0.85,1.14]
Primary education (ref)	1	[1.00,1.00]	1	[1.00,1.00]
Secondary education	0.42***	[0.32,0.55]	0.70***	[0.58,0.83]
Tertiary or higher education	0.33***	[0.24,0.44]	0.64***	[0.53,0.78]
Total Wealth (>€ 400,000)	0.44***	[0.31,0.61]	0.70***	[0.59,0.84]
Age 50-54	1	[1.00,1.00]	1	[1.00,1.00]
55-59	0.88	[0.62,1.24]	0.9	[0.74,1.08]
60-64	0.94	[0.64,1.38]	0.78*	[0.63,0.95]

65-69	1.07	[0.75,1.54]	0.67***	[0.53,0.85]
70-74	1.08	[0.71,1.66]	0.63**	[0.48,0.84]
75-79	1.59	[0.94,2.70]	0.81	[0.57,1.16]
80+	3.27***	[1.84,5.79]	0.7	[0.38,1.30]
Hypertension	0.9	[0.65,1.23]	0.98	[0.83,1.16]
Diabetes	1.21	[0.75,1.96]	0.96	[0.71,1.30]
Stroke	2.07*	[1.07,3.99]	1.78**	[1.18,2.70]
Not depressed (CES-D < 8)	1	[1.00,1.00]	1	[1.00,1.00]
Sub-threshold depressive symptoms (CES-D 8-15)	2.14***	[1.57,2.92]	1.70***	[1.41,2.05]
Significant depression (CES-D >=16)	3.89***	[2.71,5.56]	1.94***	[1.41,2.67]

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

+ Analyses are adjusted for clustered sample design and sampling weights. Participants suffering from Dementia, Parkinson's Disease and serious memory impairment (all by self-report) were excluded from the analysis because they present cognitive impairment or neurologic illness that could influence the relationship between cognition and self-reported vision.