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Vision impairment and depression among older adults in low- and middle-income countries

Short Running Title: Vision and depression in developing countries

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Objectives

To investigate the association between visual impairment (VI) and depression in low- and middle-income countries (LMICs) and the mediating role of disability and social participation.

Methods/Design

The World Health Organization Study on global AGEing and adult health (SAGE) provided data on objective and subjective visual function, depression, disability (WHODAS-12), and social participation for nationally-representative samples of adults 50 years and older in China, India, Ghana, Mexico, Russia, and South Africa. Multivariable logistic and linear models were used to test the association between VI and depression and the indirect pathways through disability and social participation. Analyses were adjusted for sociodemographics, medical comorbidities, and complex survey design features.

Results

Visual acuity was worse in respondents with depression compared to those without depression in China (0.32 vs 0.23 logMAR; p<.001), Ghana (0.26 vs 0.18 logMAR; p<.001), and India (0.36 vs 0.30 logMAR; p<.001); self-reported vision was also significantly worse in these three countries, but not in Mexico, Russia, or South Africa. Greater disability significantly mediated the association of both objective and self-reported VI with depression in China and India. Social participation significantly mediated the association between subjective vision and depression in Ghana.

Conclusions

There is variability in the association between VI and depression across LMICs and in the mediating role of disability and social participation. Culture-specific instruments may be needed

to better characterize the association between VI and depression and further research is needed to assess causality.

Key words: depression; vision; blindness; low and middle income countries; LMIC; activity restriction model; social participation; disability

Key Points:

1. The association between vision impairment and depression varied among low- and middle-income countries in the SAGE study, with a significant association detected in China, Ghana, and India.
2. The Activity Restriction Model of depressed affect accounted for a significant portion of the association between depression and vision impairment in some countries.
3. Disability was a significant mediator between vision impairment and depression in China and India.
4. Validated culture-specific instruments to assess depression, disability, and social participation may provide a better understanding of the association between depression and chronic conditions like vision impairment.

INTRODUCTION

Poor vision and depression are both important contributors to the global burden of disease in older adults.[1,2] Distance vision impairment (VI) and blindness affect more than 250 million people worldwide,[3] with 90% of these individuals living in low- and middle-income countries (LMICs) and 82% aged 50 years or older.[4] Similarly, depression impacts 5-7% of the older population globally.[5] Both poor vision and depression in later life are associated with decreased independence and health-related quality of life, and an increased risk of dementia, disability, social isolation, and mortality.[6,7]

Prior studies indicate that older adults with VI are more likely to experience depressive symptoms compared to those with normal vision.[8–14] The reasons for this association are not fully known, but the Activity Restriction Model (ARM) of Depressed Affect offers one potential pathway to account for the link between a chronic health stressor, like VI, and depression.[15] The ARM posits that chronic health conditions lead to depression in part through limiting an individual's social participation and daily activities.[16–18] This model has been supported by prior studies on various health conditions, including stroke, limb amputation, chronic pain, osteoarthritis, and cancer.[19–24]

Bookwala and Lawson applied the ARM to the study of VI and depression in a nationally-representative sample of older adults in the U.S.[17] They found that the relationship between self-reported VI and depressive symptoms was mediated by physical limitations and feelings of isolation, but that this association did not exist between objectively-measured visual acuity and depressive symptoms. The association between VI and social participation in high-income countries has been also previously reported.[25–29] This literature suggests that the extent

of social participation in older adults with VI is related to an individual's physical and psychological health. Additionally, the transition from normal to impaired vision and the stigma associated with VI may impact social participation through their effect on self-identity.[29]

However, little is known about the relationships between poor vision, mental health, and mediating factors in non-Western and LMICs. In one prior study, investigators pooled data from six LMICs and found that poor vision was associated with increased odds of depression,[30] but this study did not analyze between-country variation, and employed very broad categories in which those with normal vision (e.g. 0.0 logarithm of the minimum angle of resolution [logMAR] or 6/6 Snellen acuity) and mild VI (e.g. 0.48 logMAR or 6/18 Snellen acuity) were grouped together.[31] Another study, from Shanghai, China, found that instrumental activities of daily living and social support partially mediated the relationship between VI and depressive symptoms.[32] However, this study relied solely on self-reported vision status and a geographically circumscribed sample. Although there is little data on the applicability of the ARM for VI in individuals living in LMICs, such studies are important in order to better understand how mental and behavioral health associations with poor vision vary based on place and culture. The current study used data from the World Health Organization (WHO) Study on global AGEing and adult health (SAGE), which consists of nationally-representative samples of adults 50 and older from China, Ghana, India, Mexico, South Africa, and Russia to investigate the association between VI and depression in LMICs. Further, the ARM was tested as a conceptual model to quantify the mediating role of disability and social participation. We anticipated that the relationship between vision and depression, and the mediating effect of disability and social

participation, would vary across the six LMICs due to the distinct cultures and medical systems in these six countries.

METHODS

The conceptual model depicting the application of the ARM to the relationship between vision and depression is presented in Figure 1.

*[*Insert Figure 1*]*

Data Source

SAGE is a recurring survey on health and well-being that consists of nationally-representative samples from China, Ghana, India, Mexico, Russia, and South Africa. This study employed cross-sectional data from Wave 1 (collected 2007-2010) since data from subsequent waves were not yet publicly available at the time of analysis. Adults age 50 and older are over-sampled in SAGE and data from these respondents comprised the analytic sample for this study. Data from SAGE are made publically available for download.[33]

Based on the World Health Survey, SAGE used probability sampling with multi-stage, stratified, random cluster samples.[34] Sample weighting included sample selection and post-stratification factors to ensure that samples were nationally-representative. Trained interviewers administered the survey in each respondent's native language.[34] When a respondent was unable to complete the survey, data were collected from a proxy respondent. The University of Michigan Institutional Review Board deemed this study exempt since it consisted of analyses of publicly available de-identified data.

Variable Definitions

Depression

Depression was determined using diagnostic criteria from the International Classification of Diseases, 10th edition (ICD-10),[31] or if the respondent reported being under treatment for depression in the past 12 months and/or having received a diagnosis of depression. To meet the ICD-10 criteria for depression, a respondent must have had a period in the last 12 months that lasted for at least 2 weeks when they met ≥2 of the following criteria: felt sad, empty or depressed most of the day, nearly every day (Q4042, Q4046); lost interest in activities that were previously enjoyable (Q4043); and/or had decreased energy or increased fatigue (Q4044). In addition, they were required to have ≥1 additional criterion from Q4047-Q4059 (loss of appetite, slowed thinking, fatigue, waking early, difficulty concentrating, slowed movement, anxiety and worry, restlessness, loss of confidence, hopelessness, decreased interest in sex, suicidal ideation, and/or suicide attempt) so that the total number of depressive criteria was ≥4.

Vision impairment

Distance visual acuity was measured using the Tumbling E logMAR chart at 4 meters separately for each eye with the individual's existing corrective lenses, if available. Data were recorded in decimal format and converted to a log scale (-log [decimal acuity]) corresponding to the logMAR acuity where 0.00 represents normal (6/6 or 20/20) vision and higher values represent worse vision. Subjective vision was determined based on responses to the question "In the last 30 days, how much difficulty did you have in seeing and recognizing an object or a

person you know across the road (from a distance of about 20 meters?" Responses were recorded on a 5-point Likert scale ranging from "none" to "extreme/cannot do".

Disability and Social Participation

Activity restrictions and disability were measured using the 12-item WHO Disability Assessment Schedule 2.0 (WHODAS).[35] Survey items were related to self-reported difficulty conducting daily activities over the past 30 days. The WHO has previously validated this measure in LMICs[36] and each item was scored on a 5-point Likert scale and a score from 0-100% was calculated using the recommended scoring algorithm, with a higher number representing greater disability.

Social participation was measured using the 9-items in the Social Cohesion section of SAGE. The survey items asked about respondents' involvement in their community in the last 12 months (Q6001 to Q6009: attended public meetings; met with a community leader; attended group, club, or organization meeting; worked with others to improve neighborhood; had friends to your home; visited with someone from a different neighborhood; socialized with coworkers; attended religious services; attended social activities) and were scored from 1 (never) to 5 (daily). Using the method described by Kulkarni et al, scores from the 9-items were summed to create a summary social participation score.[37] Cronbach's α for this scale was 0.63 in China, 0.80 in Ghana, 0.73 in India, 0.72 in Mexico, 0.72 in Russia, and 0.74 in South Africa, indicating an acceptable level of internal consistency across all countries except China, where α was below the commonly accepted acceptable threshold of 0.7.[38]

Covariates

Models were adjusted for conceptually relevant covariates in order to address potential confounding and differences in the distribution of key variables across the 6 countries. Covariates that were included in the models were age, sex, educational attainment (no formal schooling, less than primary school, completed primary school, completed secondary school, or completed college/graduate education), count of self-reported medical co-morbidities (angina, arthritis, asthma, diabetes, hypertension, lung disease, stroke), and wealth. Since measurement error and bias are common in reporting of income in LMICs, wealth was determined based on household consumption, which is a more accurate measure of permanent income in LMICs.[39] The wealth index employed in this study accounted for household assets and attributes such as ownership of durable goods (e.g. livestock, television), services (e.g. internet, water source), and household characteristics (e.g. cooking fuel, material of roof). A random effects model was used to estimate household assets and Bayesian post-estimation was used to generate estimates corresponding to each household's relative wealth in their country. Households were then divided into wealth quintiles.[39]

Data Analyses

Analyses were limited to respondents age 50 and older with complete data for basic demographic characteristics (age, sex, education, wealth, medical comorbidities) and key variables of interest for our analysis (depression, disability, social participation, and distance visual acuity objective and subjective). All analyses were conducted in R version 3.6.1 (R Foundation for Statistical Computing, Vienna, Austria). Spearman correlations were calculated

between visual acuity and self-reported vision for each of the six countries. T-tests were used to compare logMAR visual acuity by depression status in each country and the Kruskal-Walis test was used to compare the distribution of Likert-scored data on self-reported vision. Mediation analyses were undertaken in countries where there was a significant association between vision and depression.

Mediation analyses were performed to test the ARM using the *survey* [40] and *mediation* [41] packages in R. The mediation package implements the mediation approach of Imai et al.[42] Briefly, models are defined for: (i) the mediator as a function of the exposure and confounders and (ii) the outcome as a function of the mediator, exposure, and confounders. These models are combined in the Neyman-Rubin causal model counterfactual framework to produce estimates of the total effect of the exposure on the outcome and of the effect of the exposure on the outcome via the mediator. Effects are defined for a specified difference in the exposure. We present results for a 1.0-unit change on the continuous logMAR vision scale (this corresponds, for example, to the difference between normal distance visual acuity [6/6 or 20/20] and severe VI [6/60 or 20/200], as defined in the WHO International Classification of Diseases).[43] In models containing self-reported visual difficulty, regression coefficients represent a change in the scale from “none” (1) to “severe” (4) in order to be consistent with the approach used to analyze objectively assessed vision. Two mediators, WHODAS disability score (range: 0-100) and the social participation index (range: 9-45), were analyzed in separate models. Mediators were modeled using linear models, while the outcome (depression) was modeled with logistic models.

In the mediation models, the total effect represents the difference in the probability of depression comparing severe VI and normal vision using the aforementioned definitions. The

direct effect is the change in probability of depression that is not accounted for by mediators, and the average causal mediation effect (ACME) is the change in probability that is accounted for by mediators. The ACME can be expressed as a percentage of the total effect.

All models accounted for the complex survey structure in order to make point and variance estimates. Larger models that allowed for interactions between the exposure and mediator on the outcome showed no differential effect and are therefore not presented. There was also no significant interaction between age and the primary predictor variables. $P \leq 0.05$ was considered statistically significant and all hypothesis tests were two-tailed.

RESULTS

Complete data were available for 90.3% of the study sample in China, 86.9% in Ghana, 88.5% in India, 90.2% in Mexico, 77.6% in Russia, and 68.8% in South Africa. Characteristics of the analytic samples from all six countries are presented in Table 1. Visual acuity in the better-seeing eye was significantly worse among respondents with depression compared to those without depression in China (0.32 vs 0.23 logMAR; p=.004), Ghana (0.26 vs 0.18 logMAR; p<.001), India (0.36 vs 0.30 logMAR; p<.001), but not Mexico (0.23 vs 0.26 logMAR; p=0.19), Russia (0.40 vs 0.33 logMAR; p=0.10), or South Africa (0.23 vs 0.21 logMAR; p=0.51).

*[*Insert Table 1A*]*

*[*Insert Table 1B*]*

The proportion of the study sample with VI and with depression in each country is indicated in Table 2. The association between self-reported vision and depression was also

significant only in China (severe/extreme VI: 7.8% vs 2.9%; p<.001), Ghana (severe/extreme VI: 15.4% vs 10.2%; p<.001), and India (severe/extreme VI: 22.8% vs 14.8%; p<.001). *[*Insert Table 2*].* Correlations between logMAR visual acuity and self-reported vision were weakly positive (Table 3), ranging from ρ=0.07 to 0.38. *[*Insert Table 3*]*

Mediation Analyses

Table 4 presents the full results of mediation analyses, which were performed for each of the three countries (China, Ghana, and India) in which there was a significant association between vision and depression. In all three countries, respondents with depression had significantly greater disability, while social participation scores were lower only in China. *[*Insert Table 4*]*

The association between worse objective vision and depression was significantly mediated by disability in China and India. Low levels of social participation did not significantly mediate the association between worse objective vision and an increased probability of depression in any country. The results of these mediation models are depicted in Figure 2A. The association between worse self-reported vision and depression was significantly mediated by disability in both China and India. Social participation mediated the association between worse self-reported vision and depression only in Ghana. The results of these mediation models are depicted in Figure 2B.

*[*Insert Figure 2A*]*

*[*Insert Figure 2B*]*

DISCUSSION

Understanding the context-specific relationship between poor vision and depression is important for devising relevant interventions to address the mental and behavioral health consequences of VI and to promote well-being for older adults worldwide. This study, using nationally-representative data from six LMICs, tested the ARM to determine whether disability and social participation mediated the association between poor vision and depression. Results varied considerably between countries, which may suggest that the ARM is applicable in some settings but not in others. Another possibility is that instruments to assess constructs like depression, disability, and social participation are not equally salient across all contexts. This is one of few studies to have examined and compared the health consequences of poor subjective and objective vision across multiple countries. Additionally, this study provides novel data on disability and social participation as mediators of the association between both poor objective and subjective vision and depression in LMICs.

Consistent with the study hypothesis, there was considerable variation in the association between vision and depression among older adults in LMICs. In China, Ghana, and India, there were small but significant associations between vision and depression. The effect sizes ranged from a significant 0.7% increase in the probability of depression with severe VI in China, to a 7% increase with severe VI in India. Additionally, no association was detected between poor vision and depression in Mexico, Russia, or South Africa. Notably, Russia and South Africa, two of the countries in which no association was detected, also had the highest proportion of missing data among countries in this study (22% and 31%, respectively). The high rate of missing data in these countries could have contributed to the lack of a detected association, particularly if there

was systematic bias in these missing data. Nonetheless, the varied nature of these associations was not surprising, as it has been shown in anthropological literature that the manifestations of depression can vary widely as a function of culture and context.[44–51]

Studies from high-income countries have more consistently demonstrated an association between poor vision and depression.[8,11,12,14] It is likely that the definition and measure of depression in some LMICs may exclude individuals whose manifestations of depressive symptoms do not conform to standard Western definitions; this may in part account for the lack of a detectable association in some countries. The SAGE survey items on depressive symptoms were derived from the World Mental Health Survey Composite International Diagnostic Interview (CIDI),[52,53] and the ICD criteria for a diagnosis of depression were applied. Validation studies of the CIDI criteria in LMICs are limited. However, prior prevalence studies from LMICs are consistent with findings in this study. For example, a study from Kunming, China reported a depression prevalence of 1.09%,[54] compared to 1.6% in the current study. In a prior investigation from Chennai, India the prevalence of depression was 15.1%,[55] similar to the prevalence of 18.6% in this study.

The consistent differences between different LMICs in the prevalence of depression suggest that the risk of depression could vary considerably between countries and/or that Western diagnostic criteria may not be universally applicable. In a study comparing the standard Chinese version of the Structured Clinical Interview for the Diagnostic and Statistical Manual of Mental Disorders to one with culturally sensitive probes, the culturally sensitive version identified a 50-100% increase in the prevalence of major depressive episode.[56] This finding suggests that modified criteria may be needed to adequately detect depression in non-Western settings.[57]

Furthermore, such criteria may be needed to effectively study and mitigate the effect of health stressors like VI on depression.

Importantly, the percentage of the population with VI and with depression varied considerably, even among those countries in which there was a significant association between the two conditions. Seemingly, this might have biased the study toward detecting an association in those countries where VI and depression are most prevalent; however, Table 2 illustrates that this was not necessarily the case.

Among the three countries where an association was detected between poor vision and depression, the mediating effects of disability were also variable, with the ARM explaining one one-quarter to two-thirds of this effect in China and India but no significant effect in Ghana. This suggests that culture and context may impact the degree to which disability acts as a mediator between vision and depression. Prior studies testing the ARM for depression have used other disability assessment tools,[17,20–24] which may impact study findings.

While the ARM suggests that social participation may be an important mediator of the association between poor vision and increased odds of depression, the only country in which this was the case was Ghana. To our knowledge, this is the first study to test this relationship in LMICs. In a study of older U.S. adults, Bookwala and Lawson[17] reported that VI contributed to depression through social isolation. Other health stressors may contribute to depression in some LMICs through their effect on social activity. For example, in Columbia[58] and China,[59] activity restriction due to fear of falling was shown to contribute to depression through decreased social participation. We speculate that culturally-specific instruments to assess social participation may also be needed.[37]

There was a stronger association of depression with subjective compared to objective vision in China, Ghana, and India. This is consistent with a study from the United States that found depressive symptoms were associated with self-reported vision but not visual acuity.[60] Likewise, disability accounted for a greater proportion of the association of subjective compared to objective vision with depression in both China (57.4% vs 32.7%) and India (66.6% vs 25.7%). These findings suggest that coexisting depression may be more common among those with self-reported poor vision than among those with impaired visual acuity. As correlations between visual acuity and self-reported vision were not strong (range from ρ=0.07 in Mexico to ρ=0.38 in India), these two measures may represent distinct vision-related constructs. Additionally, depression may influence how individuals perceive disability, as measured by the WHODAS. However, since these data are cross-sectional and susceptible to reporting biases, it is also possible that depression is a cause rather than an effect of self-reported poor vision.

This study had several limitations. There were missing data that varied between countries, which may have biased results. Also, the data in this study were cross-sectional since subsequent waves of data were not available for analysis. Therefore, we cannot assess temporality or the directionality of associations. In fact, a previous study in the U.S. found that the association between VI and depression was bidirectional.[14] Further, although the data in this study were cross-sectional, variables corresponded to different time frames (e.g., depression and social participation over the past 12 months; subjective vision and disability over the past 1 month; and visual acuity at a single time point). This study also had important strengths. The SAGE data provide a unique opportunity to study complex phenomena across LMICs using consistent measures of vision, depression, and hypothesized mediators. This study also applied

a well-described model, the ARM, that has not been widely tested in LMICs in order to explain the commonly observed association between health stressors and depression.

In summary, this study found that the association between VI and depression was inconsistent across six distinct LMICs. The ARM explained a significant portion of the effect of poor vision on depression in China, Ghana, and India. However, context-specific explanatory models and assessments of depression may improve overall understanding of the effect of health stressors, like VI, on depression and lead to effective interventions to promote mental and behavioral health and to maximize well-being for aging populations globally.

DATA AVAILABILITY STATEMENT

The data is derived from public domain resources. The data that support the findings of this study are available in the National Archive of Computerized Data on Aging at [https://www.icpsr.umich.edu/icpsrweb/NACDA/], reference number [31381]. These data were derived from the following resources available in the public domain: [Study on global AGEing and adult health; https://www.who.int/healthinfo/sage/en/].

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Table 1A. Study sample characteristics for China, Ghana, and India stratified by depression status.

	China			Ghana			India		
Depression (N)	**Yes (210)**	**No (11849)**	**P**	**Yes (358)**	**No (3747)**	**P**	**Yes (1093)**	**No (5238)**	**P**
Age, %(95%CI)			0.770			<.001			0.125
50-59	41.0(32.9-49.6)	45.5(44.3-46.8)		29.6(24.6-35.2)	40.9(39.1-42.8)		44.6(39.6-49.7)	50.2(48.1-52.4)	
60-69	35.2(27.5-43.8)	32.1(30.9-33.2)		27.5(22.8-32.8)	27.6(26.0-29.3)		33.3(29.1-37.7)	30.6(28.8-32.4)	
70-79	19.6(13.9-26.9)	18.2(17.4-19.1)		25.9(21.0-31.5)	22.5(21.0-24.1)		17.0(14.2-20.2)	15.3(13.6-17.0)	
80+	4.1(1.7-9.6)	4.1(3.7-4.6)		16.9(12.5-22.6)	8.9(8.0-10.0)		5.1(3.5-7.5)	3.9(3.3-4.7)	
Sex, %(95%CI)			0.001			<.001			0.007
Male	36.0(28.5-44.2)	49.8(49.0-50.5)		38.2(32.6-44.2)	53.5(51.7-55.3)		45.8(41.9-49.7)	52.2(50.6-53.8)	
Female	64.0(55.8-71.5)	50.2(49.5-51.0)		61.8(55.8-67.4)	46.5(44.7-48.3)		54.2(50.3-58.1)	47.8(46.2-49.4)	
Education, %(95%CI)			0.016			0.037			<.001
None	32.9(25.5-41.2)	22.5(21.7-23.4)		62.1(56.1-67.7)	53.0(51.2-54.8)		61.1(56.0-66.0)	48.4(46.3-50.6)	
PS not completed	17.2(11.6-24.9)	19.6(18.7-20.5)		11.9(8.5-16.4)	10.3(9.2-11.5)		9.7(7.7-12.0)	10.1(8.8-11.5)	
PS	16.0(10.8-23.1)	21.8(20.9-22.7)		7.9(5.4-11.4)	11.2(10.1-12.4)		12.0(9.2-15.7)	15.6(14.0-17.3)	
Secondary/High School	32.4(25.5-40.2)	32.1(31.1-33.1)		15.6(12.0-19.9)	21.8(20.3-23.4)		15.2(10.9-20.8)	19.9(18.2-21.7)	
University or PG	1.5(0.5-4.0)	4.0(3.6-4.4)		2.6(0.9-7.1)	3.7(3.1-4.5)		2.0(1.1-3.6)	5.9(5.0-7.1)	
Wealth, %(95%CI)			<.001			0.091			0.001
Lowest quintile	27.2(21.1-34.4)	16.3(15.6-17.1)		16.1(12.5-20.5)	18.4(17.1-19.8)		22.3(18.4-26.8)	17.2(15.5-19.2)	
2	32.2(24.6-40.8)	18.4(17.4-19.3)		25.0(20.1-30.7)	18.5(17.1-20.0)		23.0(18.4-28.5)	18.3(16.4-20.4)	
3	17.9(11.6-26.6)	20.9(19.8-22.0)		20.5(16.0-25.9)	20.7(19.1-22.3)		18.6(15.3-22.4)	18.8(16.8-21.1)	
4	14.6(9.4-22.1)	23.5(22.4-24.7)		21.0(16.1-26.9)	20.7(19.2-22.3)		18.8(15.4-22.7)	19.9(18.0-22.0)	
Highest quintile	8.0(4.5-13.9)	20.9(19.9-21.9)		17.4(13.2-22.6)	21.7(20.2-23.3)		17.2(13.8-21.3)	25.7(23.5-28.0)	
Comorbidity,[†] %(95%CI)			<.001			<.001			<.001
0	0.0(0.0-0.0)	25.7(24.7-26.6)		0.0(0.0-0.0)	28.0(26.4-29.7)		0.0(0.0-0.0)	38.6(36.5-40.8)	
1	11.5(6.7-19.1)	40.4(39.3-41.4)		7.8(5.5-11.1)	40.6(38.8-42.4)		18.7(15.6-22.3)	32.4(30.5-34.3)	
2-8	88.5(80.9-93.3)	34.0(32.9-35.0)		92.2(88.9-94.5)	31.4(29.6-33.1)		81.3(77.7-84.4)	29.0(27.1-31.0)	
Self-Reported Vision, %			<.001			<.001			<.001
None	46.9	63.7		15.8	35.7		23.0	38.5	
Mild	21.3	24.6		28.1	27.6		28.0	26.3	

Moderate	23.9	8.8		40.8	26.6		26.2	20.5	
Severe	5.7	2.5		12.8	9.3		17.6	13.0	
Extreme	2.1	0.4		2.6	0.9		5.2	1.8	
VA,[¶] mean(95%CI)	0.32(0.26-0.37)	0.23(0.22-0.24)	0.004	0.26(0.23-0.30)	0.18(0.17-0.20)	<.001	0.36(0.34-0.39)	0.30(0.29-0.31)	<.001
Disability,[‡] mean(95%CI)	19.5(16.1-22.9)	7.2(6.9-7.4)	<.001	26.4(23.5-29.4)	19.2(18.5-19.9)	<.001	33.4(31.8-35.1)	21.6(20.9-22.4)	<.001
SP,[§] mean(95%CI)	14.4(13.6-15.1)	15.2(15.1-15.3)	0.021	24.5(23.6-25.5)	24.1(23.9-24.4)	0.434	17.6(17.2-18.0)	17.8(17.6-18.0)	0.363

[†]number of following conditions: arthritis, angina, asthma, diabetes, hypertension, lung disease, stroke, [¶]visual acuity in logMAR, [‡]scores on WHODAS range from 0-100% with higher numbers representing greater disability, [§]scores range from 9 to 45, with higher scores representing greater social participation.
Abbreviations. CI – confidence intervals, PS – primary school, PG – post-graduate, VA – visual acuity (logMAR scale), SP – social participation.

Table 1B. Study sample characteristics for Mexico, Russia, and South Africa stratified by depression status

	Mexico			Russia			South Africa		
Depression (N)	**Yes (327)**	**No (1570)**	**P**	**Yes (261)**	**No (2658)**	**P**	**Yes (136)**	**No (2505)**	**P**
Age, %(95%CI)			0.136			0.840			0.897
50-59	23.6(15.8-33.7)	16.0(13.4-19.0)		46.6(33.0-60.7)	44.3(40.1-48.6)		56.0(40.8-70.2)	50.0(46.7-53.2)	
60-69	37.5(29.9-45.7)	41.0(37.4-44.7)		25.4(15.3-38.9)	24.4(21.4-27.8)		25.1(15.3-38.5)	30.2(27.4-33.2)	
70-79	29.7(23.0-37.5)	29.2(25.7-33.0)		21.7(14.8-30.7)	22.5(19.4-25.9)		14.2(5.1-33.6)	14.3(12.3-16.6)	
80+	9.2(5.3-15.5)	13.8(11.6-16.5)		6.3(3.7-10.5)	8.7(6.7-11.3)		4.7(0.8-23.6)	5.5(4.3-7.0)	
Sex, %(95%CI)			0.001			0.002			0.070
Male	30.8(22.3-40.9)	50.0(46.6-53.3)		21.0(12.6-33.0)	41.4(38.8-44.1)		28.1(16.9-42.9)	41.7(38.9-44.6)	
Female	69.2(59.1-77.7)	50.0(46.7-53.4)		79.0(67.0-87.4)	58.6(55.9-61.2)		71.9(57.1-83.1)	58.3(55.4-61.1)	
Education, %(95%CI)			0.075			0.058			0.226
None	16.0(10.6-23.3)	22.8(19.8-26.0)		1.3(0.2-6.6)	0.6(0.3-1.2)		20.5(11.3-34.2)	24.9(22.4-27.5)	
PS not completed	38.8(31.4-46.7)	41.4(37.5-45.3)		3.6(1.6-8.3)	1.0(0.7-1.6)		35.3(23.0-49.9)	23.1(20.6-25.9)	
PS	28.9(20.6-38.9)	18.4(15.8-21.3)		4.7(2.6-8.3)	5.7(4.2-7.8)		19.9(10.7-34.0)	22.4(20.0-25.1)	
Secondary/High School	9.8(5.4-17.1)	9.8(7.0-13.6)		77.4(68.6-84.4)	74.7(70.6-78.4)		22.6(11.4-39.9)	23.2(20.4-26.2)	
University or PG	6.5(4.1-10.3)	7.7(5.9-9.8)		13.0(8.4-19.5)	17.9(14.5-22.0)		1.6(0.7-4.0)	6.4(4.7-8.6)	
Wealth, %(95%CI)			0.242			0.028			0.536
Lowest quintile	24.0(17.6-31.8)	24.9(21.7-28.4)		24.2(14.0-38.5)	16.3(13.5-19.4)		25.9(13.1-44.9)	19.4(17.0-22.1)	
2	21.4(15.8-28.2)	21.9(18.5-25.7)		14.6(8.4-24.2)	20.9(17.6-24.6)		11.1(4.5-25.0)	20.5(18.0-23.2)	
3	20.5(12.9-30.9)	15.7(13.2-18.6)		12.9(8.1-19.9)	19.7(16.5-23.4)		20.4(11.1-34.5)	18.8(16.4-21.4)	
4	21.7(15.7-29.2)	18.1(15.3-21.3)		32.2(19.1-48.8)	19.8(16.7-23.3)		19.6(11.9-30.4)	20.2(17.5-23.3)	
Highest quintile	12.5(8.6-17.8)	19.4(15.9-23.4)		16.2(10.7-23.8)	23.4(19.5-27.7)		23.0(14.1-35.2)	21.1(18.5-24.0)	
Comorbidity,[†] %(95%CI)			<.001			<.001			<.001
0	0.0(0.0-0.0)	36.5(32.9-40.2)		0.0(0.0-0.0)	17.8(14.4-21.8)		0.0(0.0-0.0)	17.8(15.5-20.4)	
1	16.0(11.1-22.5)	32.6(29.2-36.2)		4.1(1.8-8.9)	27.4(24.1-30.9)		2.9(1.1-7.5)	47.5(44.4-50.7)	
2-8	84.0(77.5-88.9)	30.9(27.7-34.4)		95.9(91.1-98.2)	54.8(50.8-58.8)		97.1(92.5-98.9)	34.7(31.8-37.8)	
Self-Reported Vision, %			0.053			0.107			0.738
None	46.6	52.9		44.4	55.5		46.2	49.2	
Mild	22.6	26.2		30.4	28.3		24.2	22.4	
Moderate	20.4	15.7		14.8	12.0		25.1	21.9	
Severe	9.1	3.3		6.8	3.7		4.5	5.7	

Extreme	1.3	1.8		3.6	0.6		0.0	0.8	
VA,[¶] mean(95%CI)	0.23(0.18-0.27)	0.26(0.24-0.28)	0.191	0.40(0.31-0.49)	0.33(0.30-0.35)	0.102	0.23(0.17-0.28)	0.21(0.19-0.23)	0.508
Disability,[‡] mean(95%CI)	22.6(19.3-25.8)	15.0(13.8-16.2)	<.001	24.8(19.5-30.1)	15.8(14.5-17.2)	0.001	28.6(22.8-34.4)	17.2(16.0-18.5)	<.001
SP,[§] mean(95%CI)	15.0(14.0-15.9)	15.4(15.0-15.8)	0.406	14.8(13.7-15.8)	15.8(15.5-16.2)	0.068	20.8(19.3-22.4)	21.4(21.0-21.7)	0.524

[†]number of following conditions: arthritis, angina, asthma, diabetes, hypertension, lung disease, stroke, [¶]visual acuity in logMAR, [‡]scores on WHODAS range from 0-100% with higher numbers representing greater disability, [§]scores range from 9 to 45, with higher scores representing greater social participation.
Abbreviations. CI – confidence intervals, PS – primary school, PG – post-graduate, VA – visual acuity (logMAR scale), SP – social participation.

Table 2. Percentage of sample with vision impairment and depression in the six SAGE countries.

	Vision Impairment,[†] %(95%CI)		Depression, %(95%CI)
	Moderate[‡]	*Severe*[§]	
China	12.5(11.8-13.2)	3.3(2.9-3.7)	1.6(1.4-1.9)
Ghana	6.9(6.0-7.9)	8.3(7.3-9.3)	8.6(7.6-9.6)
India	22.6(0.9-24.2)	5.2(4.3-6.1)	18.6(17.1-20.3)
Mexico	23.4(20.5-26.6)	2.6(1.8-3.8)	16.1(13.7-18.8)
Russia	31.8(28.1-35.8)	4.1(3.1-5.3)	7.0(5.4-9.1)
S. Africa	16.1(13.8-18.6)	2.8(2.0-3.9)	4.9(3.7-6.5)

[†]based on distance visual acuity of better seeing eye, [‡]moderate vision impairment: visual acuity from 0.48 logMAR (20/60 or 6/18) to 1.00 logMAR (20/200 or 6/60), [§]visual acuity worse than 20/200. Abbreviations. CI – confidence Interval. S.Africa—South Africa.

Table 3. Spearman correlations between visual acuity and self-reported vision[†]

	Correlation Coefficient (ρ)	*95% CI*
China	0.30	0.29-0.32
Ghana	0.29	0.27-0.32
India	0.38	0.36-0.40
Mexico	0.07	0.03-0.11
Russia	0.33	0.30-0.36
S. Africa	0.20	0.17-0.23

[†]logMAR visual acuity and self-reported vision on 5-point scale. Abbreviations. CI – confidence Interval. S.Africa—South Africa.

Table 4. Estimates of direct and indirect effects of objective and self-reported vision on depression.

	China		Ghana		India	
	Disability	*Social Participation*	*Disability*	*Social Participation*	*Disability*	*Social Participation*
Total Effect,† Estimate(95%CI)						
Objective VI	0.71(-0.01-1.57)	0.88(0.09-1.83)	3.39(0.32-6.77)	3.31(0.33-6.67)	6.53(1.13-12.16)	6.89(1.70-12.44)
Self-Reported VI	1.77(0.53-3.33)	2.02(0.69-3.72)	5.54(2.67-8.55)	5.65(2.64-8.80)	6.87(3.01-10.79)	7.16(3.34-10.99)
ADE,† Estimate(95%CI)						
Objective VI	0.48(-0.22-1.29)	0.83(0.05-1.76)	3.29(0.17-6.71)	3.46(0.47-6.83)	4.85(-0.36-10.29)	7.27(2.05-12.83)
Self-Reported VI	0.77(-0.39-2.14)	1.90(0.59-3.59)	5.98(2.75-9.39)	5.16(2.10-8.34)	2.29(-1.69-6.33)	7.22(3.40-11.07)
ACME,† Estimate(95%CI)						
Objective VI	0.24(0.14-0.36)	0.05(-0.02-0.13)	0.10(-0.43-0.66)	-0.15(-0.45-0.05)	1.68(0.83-2.64)	-0.38(-0.87--0.02)
Self-Reported VI	1.00(0.68-1.40)	0.12(-0.04-0.30)	-0.44(-2.02-1.12)	0.49(0.09-0.96)	4.57(3.44-5.83)	-0.06(-0.25-0.07)
Percent Mediation, %(95%CI)						
Objective VI	32.7(-73.0-193.9)	5.1(-5.3-25.5)	2.8(-25.0-38.0)	-4.1(-29.9-2.7)	25.7(10.3-105.6)	-5.4(-23.7--0.2)
Self-Reported VI	57.4(32.1-163.5)	5.9(-2.3-20.0)	-7.9(-43.8-21.8)	8.5(1.5-23.3)	66.6(39.5-153.3)	-0.7(-4.1-1.0)

†strength of association is measured as the difference of two probabilities, each expressed on a scale from 0 to 100. Abbreviations. CI – confidence intervals, ADE – average direct effect, ACME – average causal mediated effect.

FIGURE LEGENDS

Figure 1. The Activity Restriction Model Applied to Vision Impairment. The figure depicts the application of the Activity Restriction Model of Depressed Affect to explain the association between vision impairment and depression.

Figure 2. Forest plots of the association of vision,depression, and mediators. Panel A depicts the association of visual acuity impairment with depression and the influence of mediators. Panel B depicts the association of self-reported vision impairment with depression and the influence of mediators. *P<.05, **P<.01, ***P<.001.