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# Reading Speed as an Objective Measure of Improvement Following Vitrectomy for Symptomatic Vitreous Opacities

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1           **Reading speed as a reliable outcome measure to assess visual**  
2           **improvement following vitrectomy for symptomatic vitreous**  
3           **opacities in patients with clear lenses**

4  
5   Short title: Reading speed as an objective measure of improvement following vitrectomy for  
6   symptomatic vitreous opacities

7  
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24 **Authors' contribution:**

25

- 26 • Study concept and design: Edwin H. Ryan, Aurèlie Calabrèse, Linda Lam
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- 28 • Analysis and interpretation of data: Aurèlie Calabrèse, Edwin H. Ryan
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- 32 Christine Pulido, Steven R. Bennett

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43 vitrectomy surgery from Alcon Surgical.

44

45

46

47

48 **Abstract**

49 **Background and Objective:** There is currently no objective measure of the visual deficits  
50 experienced by patients with symptomatic vitreous opacities (SVO) that would also correlate  
51 with the functional improvement they report following vitrectomy. This study aims to determine  
52 whether reading speed can be used as a reliable outcome measure to assess objectively the  
53 impact of both SVO and vitrectomy on patients' visual performance.

54 **Study Design/Materials and Methods:** 20 adult patients seeking surgery for SVO were  
55 included. Measures of visual function were obtained before and after vitrectomy using the  
56 ETDRS acuity chart, the NEI-VFQ and the MNREAD.

57 **Results:** In patients with non-opacified lenses (N=10), maximum reading speed increased  
58 significantly from 138 to 159 words per minute after complete removal of SVO by vitrectomy  
59 (95%CI = [14, 29],  $p < 0.001$ ).

60 **Conclusion:** Reading speed is impaired with SVO, and improves following vitrectomy in phakic  
61 and pseudophakic eyes with clear lenses. Reading speed is a valid objective measure to assess  
62 the positive effect of vitrectomy for SVO on near-distance daily life activities.

63

64 **Keywords**

65

66 Vitrectomy, symptomatic vitreous opacities, lens opacity, reading speed, daily-life function, functional  
67 improvement, objective measurement

68

## 69 **Background and Objective**

70 Patients with symptomatic vitreous opacities (SVO) experience visual impairment from multiple  
71 dense particles floating in the vitreous gel, which often cast a mobile dark shadow on the retina.  
72 However, standard objective measures of visual function, such as Snellen visual acuity, remain  
73 often excellent in the presence of SVO<sup>1,2</sup>. Nonetheless, patients with SVO report significant  
74 visual improvement after their removal by vitrectomy<sup>3,4</sup>. For instance, previous studies have  
75 shown post-operative improvement in subjective visual quality of life<sup>5,6</sup>. These results were  
76 obtained with the National Eye Institute Visual Function Questionnaire (NEI-VFQ), which  
77 assesses the level of difficulty experienced by individuals with chronic eye diseases during daily-  
78 living activities, such as driving or reading<sup>7</sup>.

79

80 To complement such subjective evaluations, there is a need for establishing a quantifiable  
81 measure to assess objectively (1) the impairment in visual function caused by SVO and (2) the  
82 improvement in visual function following vitrectomy<sup>3</sup>. First, such a clinical measure would help  
83 detect patients with functional impairment from vitreous floaters. Second, it would bring  
84 valuable insight to help resolve the existing controversy over vitrectomy's clinical relevance. So  
85 far, intraocular straylight<sup>8</sup> and contrast sensitivity<sup>6</sup> have been proposed as independent objective  
86 measures of visual perception with symptomatic floaters. Despite their impact on vision-related  
87 quality of life, these measures do not evaluate daily life function directly.

88

89 A frequent complaint from patients with prominent opacities is interference with ease of reading.  
90 Even if unilateral, these patients often complain of interference with binocular visual function<sup>9,10</sup>.

91 Patients usually report moderate or extreme difficulty in reading small print<sup>5</sup>. In the low-vision  
92 literature reading speed is already considered a strong objective predictor of visual ability and  
93 vision-related quality of life for patients with ocular disorders, such as macular  
94 degeneration<sup>11,12,13,14</sup>. Here we conducted a prospective study to test whether reading  
95 performance can also be used as reliable outcome measure to investigate the impact of SVO and  
96 therapeutic vitrectomy on patients' visual performance.

97

98 Our main objective was to investigate whether reading performance, evaluated with the  
99 standardized MNREAD test, could provide an objective measure of functional improvement in  
100 patients with SVO treated with pars plana vitrectomy. To this aim, we compared pre and post-  
101 operative measures of (1) vision-related quality of life (subjectively obtained with the NEI VFQ)  
102 and (2) reading performance (objectively obtained with the MNREAD test). Given that reading  
103 performance is rapidly degraded with reduced contrast from cloudy ocular media<sup>15</sup>, these  
104 comparisons were performed while controlling for patients' lens status (clear vs. mildly  
105 opacified). Additionally, we investigated whether a potential improvement in these subjective  
106 and objective measures following vitrectomy would be correlated with pre-operative opacity  
107 severity.

108

109

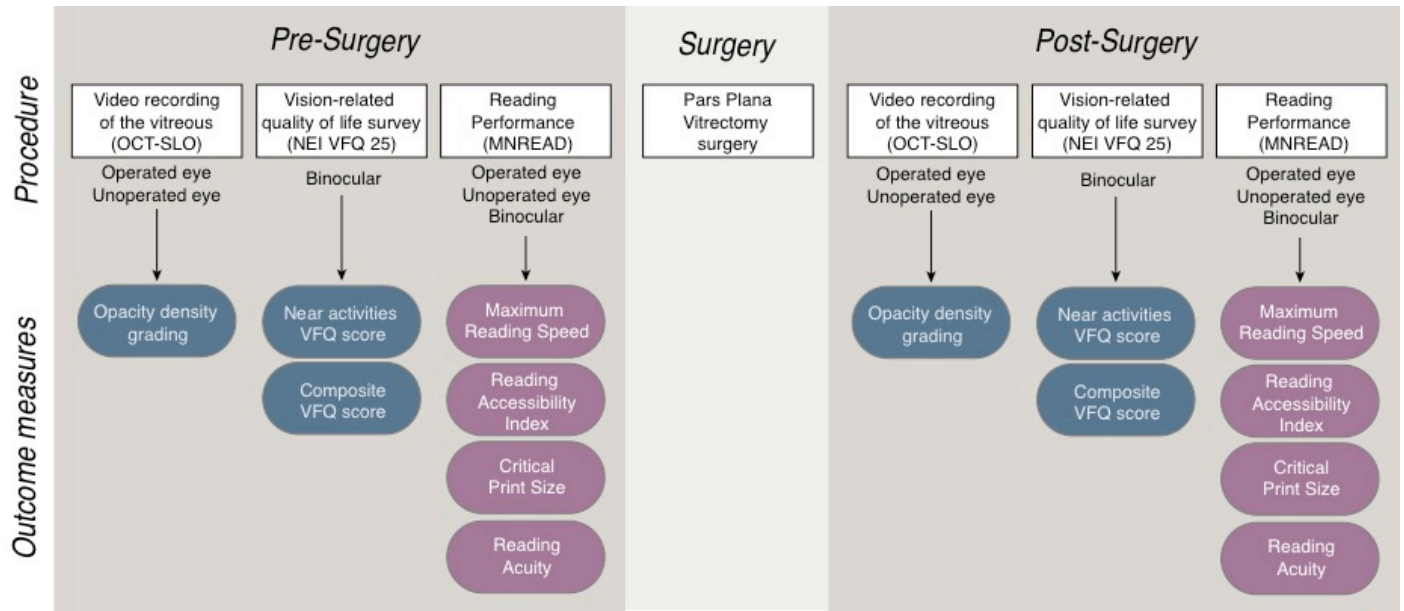
110

## 111 **Patients/Materials and Methods**

### 112 *Patients*

113 Patients over 21 years old were included in the present work if they (1) elected to undergo  
114 vitrectomy, (2) presented symptoms consistent with examination findings of dense opacities for  
115 at least 6 months, (3) had visual acuity of 20/80 (0.6 logMAR) or better in both eyes before  
116 surgery and (4) did not experience a significant drop in acuity in the non-operated eye between  
117 the pre- and post-surgery measurements. Phakic and pseudophakic patients were included, as  
118 well as patients with or without a vitreous detachment. History of scleral buckle for retinal  
119 detachment (RD) was acceptable if the macula was not involved. If an epiretinal membrane was  
120 noted on OCT but not clinically visible or deemed significant, patients were included in the  
121 study. Patients were excluded if they had history of cognitive impairment, macula-off RD, severe  
122 glaucoma, macular degeneration, diabetic macular edema, or other confounding ocular disorders.  
123 A total of 20 patients were recruited, tested and treated at two different sites: 11 at a private  
124 retina practice in Minnesota and 9 at an academic retina practice in California. Figure 1  
125 illustrates the protocol sequence. Institutional Review Board (IRB)/Ethics Committee approval  
126 was obtained and written informed consent was obtained before the study from each patient  
127 according to IRB guidelines. The study also complied with tenets of the Declaration of Helsinki  
128 and HIPAA.





129

130 **Figure 1: Protocol schematic showing the different test procedures along with the resulting outcome measures.**  
 131 **Subjective measures are represented in blue; objective measures are represented in pink.**

132

133 ***Surgery***

134 20 eyes of 20 patients underwent outpatient three-port 25-gauge pars plana vitrectomy using the  
 135 Alcon Constellation system. Inspection of the peripheral retina with indirect ophthalmoscopy and  
 136 scleral depression was performed at surgery conclusion. Leaking sclerotomies were sutured.  
 137 Postoperative examinations were at 1 day, 1-2 weeks, and 4-6 weeks. Presence or absence of a  
 138 posterior vitreous detachment (PVD) was confirmed intraoperatively. Visual acuity, intraocular  
 139 pressure, dilated funduscopy exam and any postoperative complications including high or low  
 140 intraocular pressure, retinal tear or detachment, and/or endophthalmitis were recorded. For each  
 141 patient, the non-operated eye served as control.

142

143

144 ***Subjective grading of opacity density***

145 Before and after surgery, patients went through video recording of the vitreous using the infrared  
146 confocal scanning laser ophthalmoscope (SLO) combined with optical coherence tomography  
147 (OCT)<sup>16,17</sup>. The movie created with this technique reveals motion of the shadows projected by  
148 the opacities onto the retinal surface, enabling a subjective grading of the opacity density.  
149 Recording was performed in each eye. Patients were instructed to look to one side and then re-  
150 fixate, which set the vitreous opacities in motion. This step was repeated to each side several  
151 times. The pre and post-surgery videos were assessed by two experienced, masked surgeons and  
152 given a score of 0-3, with 0 corresponding to no floaters and 3 corresponding to very dense  
153 floaters (see supplementary material for a pre-op movie graded as 2 and a post-op movie graded  
154 as 0).

155

156 ***Subjective measure of vision-related quality-of-life***

157 Before and after surgery, patients were interviewed with the NEI-VFQ-25, the 25-item version of  
158 the VFQ test<sup>7</sup>. Data were scored using the standard method to calculate: 1-the near activities  
159 VFQ score (involving reading) and 2- the composite VFQ score (encompassing many vision-  
160 related functions). Scores ranged from 0 to 100, with higher scores representing better function.

161

162 ***Objective measure of reading speed***

163 Before and after surgery, patients' reading performance was measured with the MNREAD acuity  
164 chart, a standardized test designed to measure binocular and monocular reading performance<sup>18</sup>.

165 Test measures were obtained with the MNREAD app running on an iPad<sup>19</sup>. Viewing distance  
166 was 60 cm and screen luminance was set to 200cd/m<sup>2</sup>. Patients went through six iterations of the  
167 test (operated eye, non-operated eye and binocular, each condition being repeated twice), all in  
168 black print on white background. MNREAD testing was performed pre-operatively and again 4-  
169 8 weeks after surgery. For each test performed, the four MNREAD measures were estimated  
170 internally by the app<sup>18</sup>: (1) Maximum Reading Speed (MRS), (2) Critical Print Size (CPS), (3)  
171 Reading Acuity (RA) and (4) reading ACCessibility index (ACC - a single-valued measure that  
172 represents one's visual access to commonly encountered printed material, ranging from 0 (i.e. no  
173 access to print) to 1 (i.e. average normal access) or above)<sup>20</sup>.

174

### 175 *Statistical analysis*

176 Pre and post-operative scores of NEI-VFQ were compared with a Wilcoxon signed-rank test. For  
177 each of the four MNREAD parameters, a different linear mixed-effects model including data  
178 from all 20 patients was designed to compare values before and after vitrectomy for the operated  
179 eye, the non-operated eye and the binocular condition<sup>21,22</sup>. To control for covariate factors, the  
180 following variables were also included in the models: binocular lens opacity ('clear' vs. 'mild  
181 opacity'), presence of epiretinal membrane (ERM) in the operated eye ('yes' vs. 'no'), presence  
182 of SVO in the non-operated eye ('yes' vs. 'no'), presence of posterior vitreous detachment  
183 (PVD) in the non-operated eye ('yes' vs. 'no') and testing location ('Minnesota' vs.  
184 'California'). The same random structure was chosen for all four models and included a random  
185 intercept for "eyes nested within patients", assuming a different baseline performance level for  
186 each patient and each eye. Post-hoc pairwise comparisons were performed using Tukey's

187 correction. In the Results section, mean values estimated by the models and post-hoc pairwise  
 188 comparisons are reported with their 95% confidence intervals (95%CI) and p-values.

189

190

## 191 **Results**

### 192 *Patients*

193 Preoperative clinical examination revealed the presence of SVO and clinical evidence of PVD in  
 194 all patients. Thirteen patients had bilateral but asymmetric opacities noted on clinical  
 195 examination, and were asymptomatic in the fellow eye. Six patients had concurrent minimally  
 196 significant epiretinal membrane. One patient had a history of scleral buckling for a macula-  
 197 sparing retinal detachment. Vitreous opacities symptoms had been present for 6 to 24 months.  
 198 Table 1 presents the patients' preoperative individuals characteristics.

Patient ID	Location	Gender	Age	Lens opacity in both eyes	Operated eye				Non-operated eye		
					Pathology	SVO	Acuity	OCT-SLO Opacity grading	Pathology	SVO	Acuity
P1	Minnesota	M	58	Clear	PVD	Yes	20/25	2	ERM	No	20/25
P2	Minnesota	M	59	Clear	PVD	Yes	20/20	1.5	--	Yes	20/25
P3	California	M	61	Clear	PVD	Yes	20/20	3	ERM	No	20/40
P4	Minnesota	M	62	Clear	PVD+ ERM	Yes	20/20	1.5	Scleral buckling + ERM	No	20/20
P5	Minnesota	M	64	Clear	PVD+ ERM	Yes	20/15	2	PVD	Yes	20/25
P6	Minnesota	F	64	Clear	PVD	Yes	20/25	2.5	--	Yes	20/20
P7	Minnesota	F	64	Clear	PVD	Yes	20/20	2.5	PVD	Yes	20/25
P8	Minnesota	F	68	Clear	PVD	Yes	20/30	1	PVD	Yes	20/15
P9	California	M	69	Clear	PVD	Yes	20/20	2.5	PVD	Yes	20/20
P10	Minnesota	F	72	Clear	PVD	Yes	20/25	2	PVD	Yes	20/25
P11	California	F	32	Mild opacity	PVD	Yes	20/25	1	PVD	Yes	20/80

P12	California	M	52	Mild opacity	PVD+ ERM	Yes	20/25	2.5	Vitreous Syneresis	No	20/20
P13	California	M	54	Mild opacity	PVD+ ERM	Yes	20/40	3	NPDR	No	20/20
P14	California	F	54	Mild opacity	PVD	Yes	20/25	2.5	PVD	Yes	20/80
P15	Minnesota	M	63	Mild opacity	PVD+ ERM	Yes	20/40	2.5	ERM	Yes	20/25
P16	California	M	63	Mild opacity	PVD+ ERM	Yes	20/80	2	ERM	No	20/25
P17	Minnesota	M	64	Mild opacity	PVD	Yes	20/20	2.5	Vitreous Syneresis	Yes	20/20
P18	California	F	65	Mild opacity	PVD	Yes	20/30	2.5	PVD	Yes	20/25
P19	California	F	67	Mild opacity	PVD	Yes	20/30	2.5	ERM	No	20/25
P20	Minnesota	M	68	Mild opacity	PVD	Yes	20/20	1.5	PVD	Yes	20/25

199

200 **Table 1: Patients' individual characteristics prior to surgery. SVO stands for symptomatic vitreous**  
201 **opacities; ERM stands for epiretinal membrane. PVD stands for posterior vitreous detachment;**  
202 **NPDR stands for non-proliferative diabetic retinopathy; Visual acuity is given in Snellen notation.**

203

204 ***Surgery***

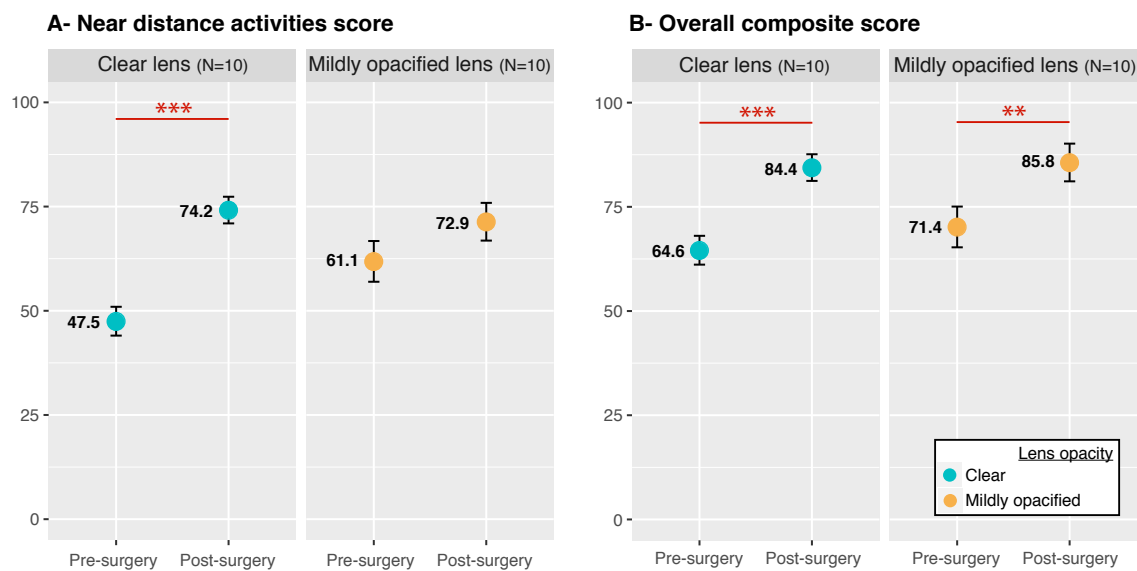
205 No complications were seen. No cataract progression was observed in phakic patients during the  
206 short period of follow-up (6 weeks). Complete removal of the central vitreous opacities was  
207 documented by examination and video SLO in all 20 cases. Prior to surgery, OCT-SLO grading  
208 of opacity was on average 2.2, ranging from 0 to 3 (Table 1). After vitrectomy, opacity grading  
209 score was 0 for all 20 patients.

210

211 ***Visual function***

212 In the operated eye, mean visual acuity was  $0.11 \pm 0.16$  logMAR before surgery and  $0.09 \pm 0.16$   
213 logMAR after surgery. The difference between pre- and post-op visual acuity was not significant  
214 ( $p = 0.36$ ). Both NEI-VFQ scores improved significantly after vitrectomy, but this improvement  
215 was dependent on the lens opacity (Figure 2). Among patients with clear lenses (N=10), the

216 average near activities sub-score went from 47.5 to 74.2. This significant increase of 26.7 points  
 217 (95%CI = [16.2, 37.1],  $p < 0.001$ ) corresponds to an overall 56.2% improvement (Figure 2A-  
 218 left). For patients with opacified lenses however (N=10), vitrectomy did not improve the near  
 219 activities sub-score. For patients with clear lenses, the average pre-op composite score was 64.6  
 220 and increased by 19.8 points (95%CI = [13.9, 25.7],  $p < 0.001$ ) after vitrectomy, representing a  
 221 30.6% improvement (Figure 2B-left). The improvement was somewhat smaller for patients with  
 222 opacified lenses, whose score went from 71.4 to 85.8, representing a significant gain of 20.2%  
 223 (14.4 points, 95%CI = [-6.3, 23.4],  $p = 0.003$ ). The overall improvement for both subgroups on  
 224 the composite score was 26.3%. There was no correlation between the opacity grading score  
 225 prior surgery and the amount of NEI-VFQ score improvement following surgery (Pearson's  
 226 correlation coefficients was -0.36 and -0.39 for the near activities sub-score and the composite  
 227 score respectively).



228

229 **Figure 2: Pre and post-operative NEI-VFQ scores grouped by lens opacity status. Points show the**  
 230 **mean estimates for the near activity sub-score (A) and the overall composite score (B), both before**  
 231 **and after surgery, as estimated by the mixed effects models, for patients with clear lenses in blue**

232 (N=10) and patients with mildly opacified lenses in orange (N=10). Error bars represent the 95%  
233 confidence intervals.

234

### 235 *Reading performance*

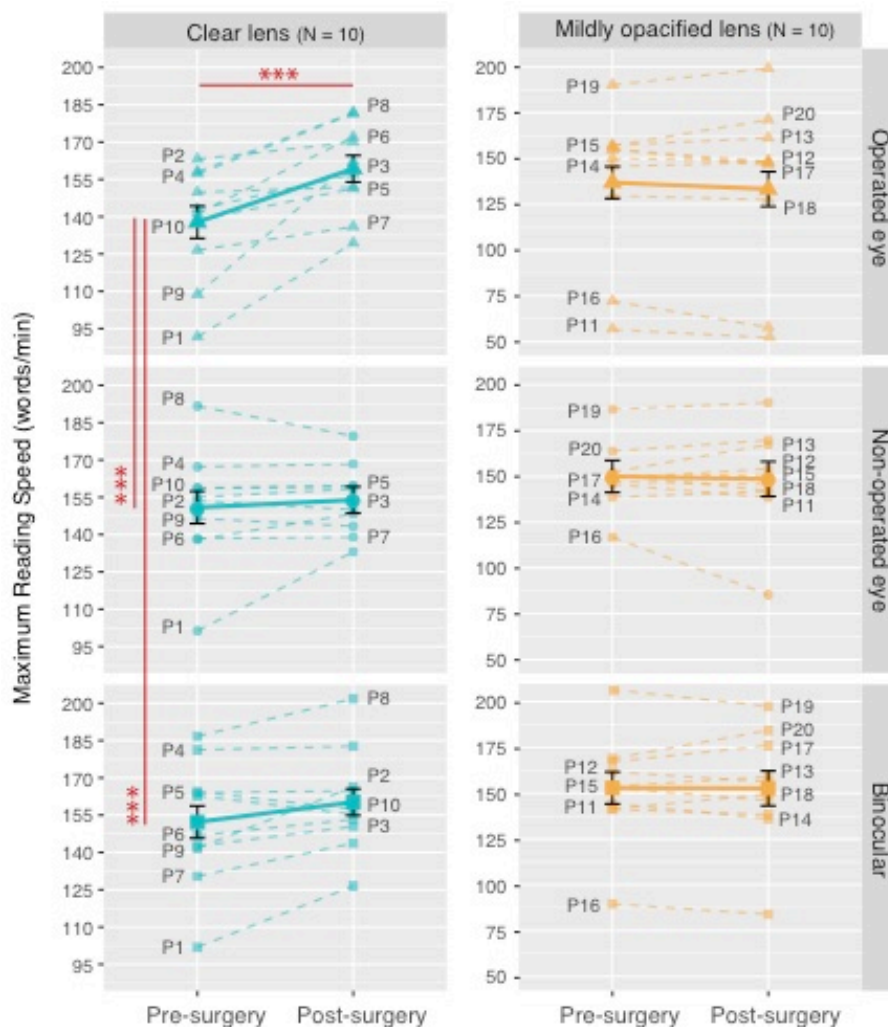
#### 236 Maximum Reading Speed (MRS)

237 First, we included data from all 20 patients in the mixed-effects model without any distinction on  
238 their lens opacity status. MRS before surgery was on average 137 words/minute (wpm) for the  
239 operated eye (95%CI = [125, 149]). It was significantly higher by 13 wpm in the non-operated  
240 eye (95%CI = [5, 22],  $p = 0.003$ ) and by 15 wpm in the binocular condition (95%CI = [7, 24],  $p$   
241  $< 0.001$ ). After surgery, MRS in the operated eye increased significantly to 146 wpm (i.e. a 9  
242 wpm increase; 95%CI = [3, 15],  $p = 0.007$ ). Post-operatively, MRS did not change significantly  
243 in the non-operated eye (1 wpm increase; 95%CI = [-12, 14];  $p = 0.8$ ) or in the binocular  
244 condition (3 wpm increase; 95%CI = [-9, 17];  $p = 0.23$ ).

245 Second, we included an interaction between the “surgery” and “lens opacity” factors in the  
246 model. For patients with clear lenses only (N=10), MRS prior surgery was on average 138  
247 words/minute (wpm) for the operated eye (95%CI = [120, 156]; Figure 3-left panel). It was  
248 significantly higher by 13 wpm in the non-operated eye (95%CI = [6, 20],  $p < 0.001$ ) and by 14  
249 wpm in the binocular condition (95%CI = [7, 22],  $p < 0.001$ ). After surgery, MRS in the  
250 operated eye increased significantly to 159 wpm (i.e. a 21 wpm increase; 95%CI = [14, 29],  $p <$   
251  $0.001$ ). In the non-operated eye, MRS did not change post-operatively, with a non-significant  
252 increase of 3 wpm (95%CI = [-7, 39],  $p = 0.43$ ). In the binocular condition, the limited increase  
253 of 8 wpm following vitrectomy barely reached significance (95%CI = [-0.38, 45],  $p = 0.04$ ).

254 For patients with mildly opacified lenses (N=10), there was no significant difference in MRS  
 255 before and after surgery in any of the three conditions tested (operated eye, un-operated eye and  
 256 binocular; Figure 3-right panel).

257 For all 20 patients there was no correlation between the opacity grading score in the operated eye  
 258 prior surgery and the amount of MRS improvement following surgery (Pearson's correlation  
 259 coefficients was -0.13).



260

261 **Figure 3: Effect of pre/post-surgery condition on MRS for the operated eye (top – triangles), the**  
 262 **non-operated eye (center - circles) and the binocular condition (bottom – squares) grouped by lens**  
 263 **opacity: clear (left – blue) vs. mildly opacified (right - orange). Solid lines connect the estimates for**



264 **each sub-group as given by the mixed-effects model. Errors bars (black) represent their standard**  
265 **errors. Dashed lines connect the MRS values for each patient, numbered from P1 to P20.**  
266

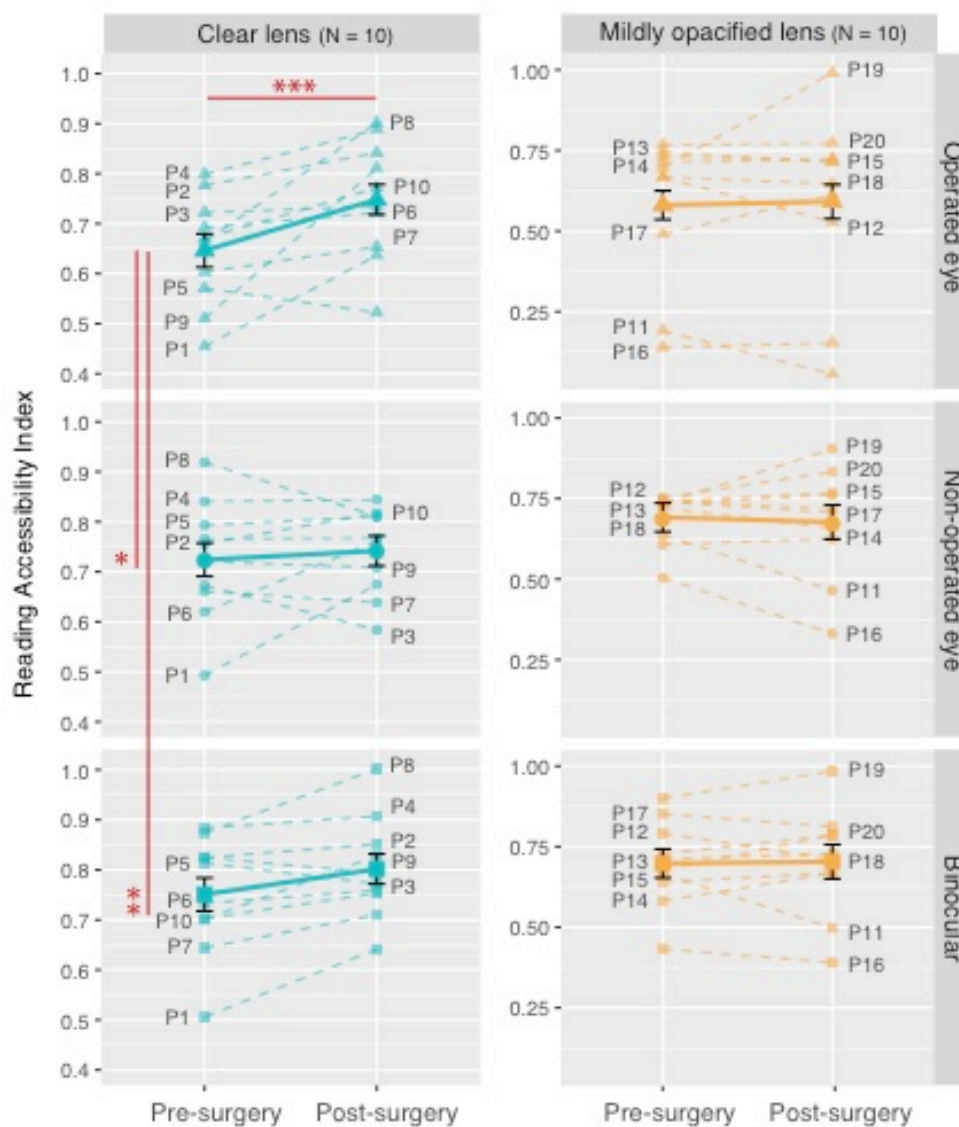
### 267 Reading Accessibility Index (ACC)

268 As for MRS, we first included data from all 20 patients in the mixed-effects model, without any  
269 distinction on their lens opacity status. Before surgery, ACC was on average 0.61 for the  
270 operated eye (95%CI = [0.55, 0.68]). It was significantly higher by 0.09 wpm in the non-  
271 operated eye (95%CI = [0.04, 0.15],  $p = 0.002$ ) and by 0.11 in the binocular condition (95%CI  
272 = [0.05, 0.17],  $p < 0.001$ ). After surgery, ACC in the operated eye increased significantly to 0.67  
273 (i.e. a 0.06 increase; 95%CI = [0.01, 0.10],  $p = 0.01$ ). Post-operatively, ACC did not change  
274 significantly in the non-operated eye (0.002 increase; 95%CI = [-0.09, 0.09];  $p = 0.95$ ) or in the  
275 binocular condition (0.03 increase; 95%CI = [-0.06, 0.12];  $p = 0.22$ ).

276 Second, we included an interaction between the “surgery” and “lens opacity” factors in the  
277 model. For patients with clear lenses only (N=10), ACC was 0.65 in the operated eye before  
278 surgery (95%CI = [0.56, 0.74],  $p < 0.001$ ; Figure 4 - left). It was marginally but significantly  
279 better for the non-operated eye, with a value of 0.72 (0.07 difference; 95%CI = [0.01, 0.14],  $p =$   
280 0.02) and significantly better in the binocular condition, with a value of 0.75 (0.1 difference;  
281 95%CI = [0.04, 0.17],  $p = 0.002$ ). Following surgery, ACC was significantly increased by 0.1 in  
282 the operated eye (95%CI = [0.05, 0.16],  $p < 0.001$ ), reaching a value of 0.75. In the non-operated  
283 eye, ACC remained unchanged after surgery (0.01 difference; 95%CI = [-0.09, 0.28],  $p = 0.5$ ).  
284 In the binocular condition, ACC increased by 0.05 after vitrectomy but this change did not reach  
285 significance (95%CI = [-0.03, 0.34],  $p = 0.06$ ).

286 For patients with mildly opacified lenses (N=10), there was no significant difference in ACC  
 287 before and after surgery in any of the three conditions tested (operated eye, un-operated eye and  
 288 binocular; Figure 4 – right panel).

289 For all 20 patients, there was no correlation between the opacity grading score prior surgery in  
 290 the operated eye and the ACC increase following surgery (Pearson’s correlation coefficient was -  
 291 0.41).



293 **Figure 4: Effect of pre/post-surgery condition on ACC for the operated eye (top – triangles), the**  
294 **non-operated eye (center - circles) and the binocular condition (bottom – squares) grouped by lens**  
295 **opacity: clear (left – blue) vs. mildly opacified (right - orange). Solid lines connect the estimates for**  
296 **each sub-group as given by the mixed effects model. Errors bars (black) represent their standard**  
297 **errors. Dashed lines connect the MRS values for each patient, numbered from P1 to P20.**  
298

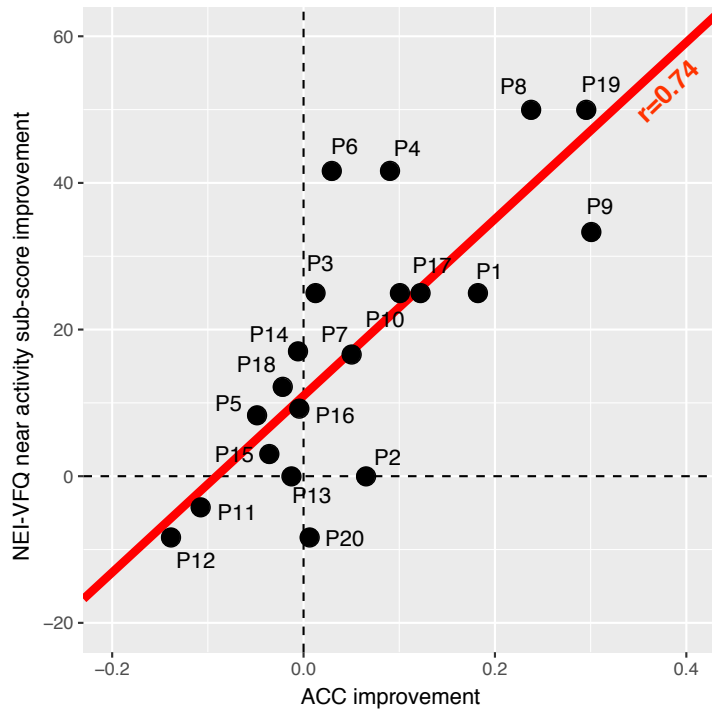
299 Critical Print size (CPS) and Reading Acuity (RA)

300 For both CPS and RA, we found no significant difference between the operated eye and the non-  
301 operated eye or the binocular condition before surgery. None of these measures changed  
302 significantly after surgery in the tested eyes.

303

304 ***Correlation between reading performance change and daily life visual function improvement***

305 Lastly, we inspected the correlation between the improvement in reading performance and the  
306 improvement in NEI-VFQ near activities sub-score in the operated eye of all 20 patients. We  
307 found no correlation between the percentage of improvement in MRS and the increase in NEI-  
308 VFQ near activities sub-score ( $r = 0.4$ ,  $95\%CI = [-0.12, 0.75]$ ,  $p = 0.12$ ). On the other hand, the  
309 improvement in ACC was significantly correlated with the near activities sub-score ( $r = 0.74$ ,  
310  $95\%CI = [0.39, 0.90]$ ,  $p = 0.001$ ; Figure 5).



311

312 **Figure 5: Post-operative NEI-VFQ near activity sub-score improvement as a function of post-**  
 313 **operative reading accessibility index improvement for all 20 patients.**

314

## 315 Discussion

316

317 The symptomatic relief experienced by patients following vitrectomy has been demonstrated  
 318 before by the use of the NEI-VFQ subjective test<sup>5,6</sup>. Our study confirmed the literature results,  
 319 with a significant overall improvement of 26% on the test composite score. This value is in line  
 320 with previously reported improvement results, ranging from 19% to 29%, in patients treated for  
 321 symptomatic floaters<sup>6,23</sup>. The present analysis also revealed a significant interaction between the  
 322 impact of surgery on the VFQ scores and the opacity status of the patient's lenses. For near  
 323 distance activities, vitrectomy only improved patients' score if their lenses were clear, whereas  
 324 the overall composite score (which includes both near- and far-distance activities) improved even

325 if the lenses were mildly opacified. To our knowledge, this result was never reported before and  
326 suggests that the removal of SVO may have a significant impact on near-distance daily life  
327 activities, but only in the absence of cataract or lens opacification. Because near distance  
328 activities rely on fine central vision, for which performance is rapidly degraded past a critical  
329 contrast threshold<sup>24</sup>, SVO removal may not be sufficient to help improve performance if contrast  
330 sensitivity is still reduced from lens opacification.

331  
332 Our second result is the poor MRS achieved in all 10 patients with SVO and clear lenses (138  
333 wpm on average in the operated eye prior surgery) compared to normal values. According to  
334 Calabrèse et al., 2016, normal readers between 58 to 68 years old should reach a MRS comprised  
335 between 183.2 and 189.2 wpm when reading with one or both eyes<sup>25,26</sup>. This 35% decrease  
336 suggests that reading speed may be considered as an objective measure of functional impairment  
337 in the presence of SVO. However, this finding should be interpreted with caution, given that  
338 other confounding clinical factors (e.g. cognitive or visual) may have also contributed to  
339 reducing reading speed.

340  
341 Our third outcome is the significant change in MRS, measured after vitrectomy in patients with  
342 clear lenses, with a 15% improvement in the operated eye. For these patients, the non-operated  
343 eye served as control and showed no improvement post-surgery, confirming that the  
344 improvement measured in the fellow eye was not due to a practice effect. More importantly, this  
345 improvement did not occur in eyes with mildly opacified lenses, either from cataract (phakic  
346 eyes) or posterior capsule opacification (pseudophakic eyes). Taken all together, these results  
347 suggest that reading speed may be a valid objective measure to quantify the positive impact of

348 vitrectomy on visual function, but only if contrast sensitivity is not still altered by lens  
349 opacification. There is evidence that a main effect of vitrectomy is to restore normal contrast  
350 sensitivity function for individuals with clear lenses<sup>6,27</sup>. We hypothesize that for patients with  
351 mildly opacified lenses, who experienced no post-surgery improvement in MRS, reduced  
352 contrast sensitivity from cloudy ocular media created a bottleneck for any potential increase in  
353 reading speed. We noted that binocular MRS was not improved post-surgery. Since, our  
354 population was not restricted to patients with non-pathological fellow eyes, we did not expect to  
355 see monocular vitrectomy having a significant impact on binocular performance.

356  
357 ACC showed the same pattern as MRS, suggesting that this measure, which is potentially  
358 quicker to obtain (in terms of testing and calculation time), could be a good alternative in clinical  
359 settings where time is often limited. More interestingly, the improvement in ACC induced by  
360 vitrectomy was significantly correlated with the improvement in near distance activities score  
361 measured with the NEI-VFQ. This result alone suggests that improved reading performance  
362 following vitrectomy will also have a positive impact on the overall patients' quality of life. The  
363 simple objective assessment of ACC post-operatively may therefore provide some insight to the  
364 patient and his/her care team about his/her overall quality of life improvement.

365  
366 Surprisingly, neither CPS nor RA were sensitive to the presence of dense floaters. Even more,  
367 we found no effect of vitrectomy on any of these measures. In their study of 110 treated eyes,  
368 Nie et al., 2013 reported that 71% of their patients had difficulty in reading small print, which  
369 markedly improved after surgery<sup>5</sup>. Based on their results, we had hypothesized that RA (i.e. the  
370 smallest print one can read) would improve following vitrectomy. However, our results do not

371 support this hypothesis and suggest that these reading measures may not be valid to quantify the  
372 impact of floaters on daily visual function.

373

374 We had expected patients with the eyes having the most prominent vitreous opacities to exhibit  
375 the greatest improvement in both NEI-VFQ scores and reading performance. This was not the  
376 case. In clinical practice, patients with a wide range of vitreous debris are seen, and often  
377 individuals with very substantial opacities can be essentially asymptomatic (as in asteroid  
378 hyalosis)<sup>28</sup>. Our result, as well as the wide variability in dysfunction among patients with similar  
379 vitreous opacities, suggests that the location and motion characteristics of the opacities may be  
380 more significant drivers than the level of opacity itself in the decision to seek symptomatic relief  
381 with surgery. However, the ability to show the degree of vitreous opacification using the video  
382 SLO was found to be helpful for educational purposes, both pre- and post-operatively. First, to  
383 show family members dynamically what the patients were seeing. Second, to help persuading  
384 patients with significant complaints but mild opacities on SLO testing that surgery would not be  
385 prudent. Finally, to document the absence of the opacities post-surgery.

386

387 Our work presents some limitations. The main one is the restricted number of patients. In the  
388 future, our results should be replicated with larger sets of patients to confirm our findings.  
389 Another limitation is that, given the nature of the MNREAD, the current study only measured  
390 fluent reading for short sentences. Therefore, it remains to be determined whether speed is also  
391 improved (and to what extent) for spot reading (i.e. for isolated words, such as tag labels) and  
392 sustained reading (i.e. for long texts).

393

394

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397

398

## 399 **Ethical Approval**

400 This study was conducted in accordance with the Declaration of Helsinki. Ethical approval for

401 this study was obtained from the Institutional Review Board (IRB) at the University of South

402 Carolina. The collection and evaluation of all protected patient health information was performed

403 in a Health Insurance Portability and Accountability Act (HIPAA)-compliant manner.

404

## 405 **Statement of Informed Consent**

406 Written informed consent was obtained before the study from each patient according to IRB

407 guidelines, including permission for publication of all videos included herein.

408

409

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473

474

## 475 **Figure legends**

476 Figure 1: Protocol schematic showing the different test procedures along with the resulting  
477 outcome measures. Subjective measures are represented in blue; objective measures are  
478 represented in pink.

479

480 Figure 2: Pre and post-operative NEI-VFQ scores grouped by lens opacity status. Points show  
481 the mean estimates for the near activity sub-score (A) and the overall composite score (B), both  
482 before and after surgery, as estimated by the mixed effects models, for patients with clear lenses  
483 in blue (N=10) and patients with mildly opacified lenses in orange (N=10). Error bars represent  
484 the 95% confidence intervals.

485

486 Figure 3: Effect of pre/post-surgery condition on MRS for the operated eye (top – triangles), the  
487 non-operated eye (center - circles) and the binocular condition (bottom – squares) grouped by  
488 lens opacity: clear (left – blue) vs. mildly opacified (right - orange). Solid lines connect the  
489 estimates for each sub-group as given by the mixed-effects model. Errors bars (black) represent  
490 their standard errors. Dashed lines connect the MRS values for each patient, numbered from P1  
491 to P20.

492

493 Figure 4: Effect of pre/post-surgery condition on ACC for the operated eye (top – triangles), the  
494 non-operated eye (center - circles) and the binocular condition (bottom – squares) grouped by  
495 lens opacity: clear (left – blue) vs. mildly opacified (right - orange). Solid lines connect the  
496 estimates for each sub-group as given by the mixed effects model. Errors bars (black) represent  
497 their standard errors. Dashed lines connect the MRS values for each patient, numbered from P1  
498 to P20.

499

500 Figure 5: Post-operative NEI-VFQ near activity sub-score improvement as a function of post-  
501 operative reading accessibility index improvement for all 20 patients.

502

503 **Tables**

Patient ID	Location	Gender	Age	Lens opacity in both eyes	Operated eye				Non-operated eye		
					Pathology	SVO	Acuity	OCT-SLO Opacity grading	Pathology	SVO	Acuity
P1	Minnesota	M	58	Clear	PVD	Yes	20/25	2	ERM	No	20/25
P2	Minnesota	M	59	Clear	PVD	Yes	20/20	1.5	--	Yes	20/25
P3	California	M	61	Clear	PVD	Yes	20/20	3	ERM	No	20/40
P4	Minnesota	M	62	Clear	PVD+ ERM	Yes	20/20	1.5	Scleral buckling + ERM	No	20/20
P5	Minnesota	M	64	Clear	PVD+ ERM	Yes	20/15	2	PVD	Yes	20/25
P6	Minnesota	F	64	Clear	PVD	Yes	20/25	2.5	--	Yes	20/20
P7	Minnesota	F	64	Clear	PVD	Yes	20/20	2.5	PVD	Yes	20/25
P8	Minnesota	F	68	Clear	PVD	Yes	20/30	1	PVD	Yes	20/15
P9	California	M	69	Clear	PVD	Yes	20/20	2.5	PVD	Yes	20/20
P10	Minnesota	F	72	Clear	PVD	Yes	20/25	2	PVD	Yes	20/25
P11	California	F	32	Mild opacity	PVD	Yes	20/25	1	PVD	Yes	20/80
P12	California	M	52	Mild opacity	PVD+ ERM	Yes	20/25	2.5	Vitreous Syneresis	No	20/20
P13	California	M	54	Mild opacity	PVD+ ERM	Yes	20/40	3	NPDR	No	20/20
P14	California	F	54	Mild opacity	PVD	Yes	20/25	2.5	PVD	Yes	20/80
P15	Minnesota	M	63	Mild opacity	PVD+ ERM	Yes	20/40	2.5	ERM	Yes	20/25
P16	California	M	63	Mild opacity	PVD+ ERM	Yes	20/80	2	ERM	No	20/25
P17	Minnesota	M	64	Mild opacity	PVD	Yes	20/20	2.5	Vitreous Syneresis	Yes	20/20
P18	California	F	65	Mild opacity	PVD	Yes	20/30	2.5	PVD	Yes	20/25
P19	California	F	67	Mild opacity	PVD	Yes	20/30	2.5	ERM	No	20/25
P20	Minnesota	M	68	Mild opacity	PVD	Yes	20/20	1.5	PVD	Yes	20/25

504

505 Table 1: Patients' individual characteristics prior to surgery. SVO stands for symptomatic

506 vitreous opacities; ERM stands for epiretinal membrane. PVD stands for posterior vitreous

507 detachment; NPDR stands for non-proliferative diabetic retinopathy; Visual acuity is given in

508 Snellen notation.

509

510 **Supplementary material**

511           Movie 1. Video 1, preoperative video SLO. The video is live streaming of scanning laser  
512 ophthalmoscopic images from the Heidelberg OCT machine. This is recorded in "Movie Max"  
513 mode, (in avi) then converted to .mov. A patient with prominent vitreous opacities months post  
514 scleral buckling was instructed to look left and re-fixate, then look right and re-fixate. Shadows  
515 from mobile vitreous opacities were projected on the stabilized retinal surface and thus imaged  
516 with the infrared camera.

517

518           Movie 2. Video 2, postoperative video SLO. The video is recorded in the same manner  
519 (with saccades) as Video 1, and of the same eye one week post vitrectomy. Absence of  
520 shadowing from vitreous opacities is noted.