Reading Performance in Patients with Retinitis Pigmentosa: A Study Using the MNREAD Charts

Gianni Virgili,1 Chiara Pierrottet,2 Francesco Parmeggiani,3,4 Monica Pennino,1 Giovanni Giacomelli,1 Piero Steindler,4 Ugo Menchini,1 and Nicola Orzalesi2

PURPOSE. To evaluate the relationship between reading performance and severity of disease in patients with retinitis pigmentosa (RP), assessed with routine clinical psychophysical visual tests.

METHODS. Seventy-six consecutive patients with RP (145 eyes), with reading acuity of at least 1.6 logMAR (logarithm of the minimum angle of resolution) in at least one eye, were examined. Each patient underwent a complete ophthalmic evaluation, including visual acuity (Early Treatment Diabetic Retinopathy Study [ETDRS] charts), contrast sensitivity (Pelli-Robson charts), visual field perimetry (Humphrey central 30-2 full-threshold program; Carl Zeiss Meditec, Dublin, CA), and a test of reading acuity, critical print size, and maximum reading speed (Minnesota Reading charts [MNREAD]).

RESULTS. Reading acuity was 1.0 logMAR or more in the better eye of all but (6%) patients. Maximum reading speed was better than 100 words per minute in the better eye of 59 (78%) subjects. Moderate to severe reading impairment, defined as reading acuity of 0.4 logMAR or worse, was observed in the better eye of 47 (62%) patients. EDTRS visual acuity of 0.3 logMAR (20/40) or worse was 89% sensitive and 66% specific when used as a criterion to define reading impairment. Contrast sensitivity and visual acuity correlated significantly with all three reading components, whereas mean light sensitivity in the central visual field (6°) demonstrated a higher correlation with maximum reading speed. The number of years elapsed since the diagnosis of RP was a strong negative predictor of reading performance when clinical visual tests were taken into account, whereas a better reading ability characterized the patients with RP who had a higher level of education. A reduced reading speed with larger print size was found in 30 eyes (21%). This correlated with central light sensitivity, as it was more common among eyes with a mean sensitivity of <10 dB.

CONCLUSIONS. The reading performance of most patients with RP is only moderately impaired. It correlates with contrast sensitivity, visual acuity, and visual field. It should be assessed in all cases, as disability can ensue, even when visual acuity is preserved. In patients with RP with poor reading performance, there is little potential for high-magnification devices because visual field constriction affects the reading rate. (Invest Ophthalmol Vis Sci. 2004;45:3418-3424) DOI:10.1167/fovs.04-0390

Retinitis pigmentosa (RP) is a progressive tapetoretinal dystrophy that is known to limit visual performance.1-3 In the most common forms of RP, visual field restriction typically occurs before central vision is impaired, causing orientation and mobility impairment in the early stages. With the progression of the disease, although visual acuity may be preserved in the long term, patients with RP may report reading disability.2,5 Reading is a complex process involving visual and nonvisual aspects. Print size is one of the factors that mainly influence reading speed in normal and low-vision subjects.4-5 The reading speed of one individual is stable across a large range of print sizes (maximum reading speed, MRS). When the print size gets smaller, a point is reached at which reading speed begins to decline (critical print size, CPS), until the subject cannot read any word because the reading acuity (RA) limit has been reached. Print size corresponding to CPS is typically two times larger RA, a difference of 0.3 in logarithm of the minimum angle of resolution (logMAR). The Minnesota Reading (MNREAD) charts allow the simultaneous acquisition of the just-mentioned objective reading parameters.6 With these, an examination of both normal readers and subjects with mild to severe reading disability is possible, to reach their visual acuity thresholds. In the course of the MNREAD test, MRS is obtained by averaging the reading speed of the sentences with print size corresponding to CPS or larger, and it is measured in words per minute (WPM). LogWPM is used to ensure proportional percentage changes by unit of measurement and is recorded in 0.01 log unit. MNREAD charts provide an estimate of CPS that is approximated to 0.1-logMAR intervals. RA—that is, the smallest print size at which some words can be still recognized—is approximated to 0.01 logMAR by subtraction of missed words or words read incorrectly, which typically cluster between CPS and acuity limit.5,5

The primary purpose of this study was to evaluate the reading performance of patients affected by RP at different stages of progression, assessed by commonly used clinical psychophysical tests. A further purpose was to assess the effectiveness of these tests as predictors of reading impairment.

METHODS

This investigation was performed on consecutive patients with RP selected from the low-vision centers of the involved eye clinics. In all recruited patients, diagnosis was performed on the basis of fundus examination, Goldmann perimetry, automated visual field perimetry, and complete electoretinographic evaluation obtained according to International Society for Clinical Electrophysiology of Vision (ISCEV) parameters.7

Patients with bilateral RP in which visual field restriction was clearly prevalent in comparison with the central vision loss (typical RP or RP sine pigmento) were included. Patients with hearing impairment
(i.e., those with Usher syndrome) were excluded. An education of grade 3 or more was required. All the enrolled subjects gave their written informed consent to participate in the study, after a detailed description of the procedures to be used and of the purpose of the work. The local ethics committees reviewed and approved the study, which adhered to the tenets of the Declaration of Helsinki.

Each RP patient enrolled in the study attended a complete ophthalmic examination with standardized tests. Visual acuity was measured with Early Treatment Diabetic Retinopathy Study (ETDRS) charts and recorded as logMAR. Contrast sensitivity was determined with Pelli-Robson charts and recorded as log contrast sensitivity. Visual field assessment was performed with the Humphrey field analyzer, employing the central 30-2 full-threshold strategy and III white stimulus (Carl Zeiss Meditec, Dublin, CA). Retinal light sensitivity, provided by the central 30-2 map, was averaged in concentric areas every 6° from the center (0°–6°, 6°–12°, 12°–18°, 18°–24°, and 24°–30°). A grand average was also calculated. Mean sensitivity within the central 6° was taken as the central sensitivity. The Italian version of the MNREAD charts was used, according to the manual provided by the authors. A reading distance of 40 cm was used in eyes with an ETDRS acuity of 0.5 logMAR (20/40) or more, whereas a distance of 20 cm was adopted in patients with a lower acuity. An appropriate reading addition was used from age 40, up to a maximum of +2.5 or +5 D in patients aged 50 or more, at a reading distance of 40 or 20 cm, respectively. During the analysis of the MNREAD data, two objective criteria were used to identify the sentence corresponding to CPS, which was considered to be the print size at which both of these conditions are satisfied. All the following (smaller print size) sentences were read at a speed that was 1.96 times the standard deviation below the average of the previous largest print size sentences, or all the following (smaller print size) sentences were read at a speed 5% slower (25% change in WPM) than this average. When these two criteria disagreed, the print size of the largest sentence was recorded as the CPS. For example, if the two criteria suggested a CPS of 0.5 or 0.6 logMAR, the latter was assumed to be the actual CPS. This was intended to avoid averaging some more slowly read sentences in the MRS computation.

The hypothesis that some patients with RP may have a reduction of reading speed when the print size becomes very large was assessed in this study. Such a reduction of the reading speed may be due to a severe visual field restriction, so that only a few letters enter the reading field, and/or due to impairment of patients’ ability to navigate the text. An objective criterion was adopted to identify the large print size at which a decline of the reading speed begins, that is when all larger sentences were read at a lower rate in comparison with both the MRS and the sentence at which the CPS was measured.

In the case of tasks closely associated with visual acuity, such as reading, it has been shown that the measures of monocular acuity in the better eye are similar to those of binocular acuity. In this study, the binocular reading assessment was considered an ancillary examination, and was performed using chart 1 during the same session, but at least 2 hours after monocular testing, to decrease the chance of a learning effect.

In each patient of this recruited RP group, all the biomicroscopic findings concerning both anterior and posterior segments were recorded with a standard form. The lens assessment was performed according to the Lens Opacities Classification System III (LOCS III). All the diagnostic procedures performed to evaluate psychophysical and ophthalmic parameters were based on a written protocol, applied by the personnel of the low-vision centers involved in the present clinical investigation.

Descriptive Statistics and Statistical Analyses

Statistical analyses were performed on computer (mainly using STATA, ver. 8.1; Stata, College Station, TX). The relationship between reading and clinical variables was presented in scatterplots using locally weighted regression.

The Spearman rank coefficient was used to evaluate the correlation of reading variables with other psychophysical measures, such as ETDRS acuity, contrast sensitivity, and retinal light sensitivity. These analyses were conducted separately in the better and worse eyes, as defined by the predictor variable.

We used a Wilcoxon rank sum test to assess the differences between monocular and binocular reading performance, and also computed the intraclass correlation coefficients (ICC). Unlike Pearson’s correlation coefficients, the ICC estimates of the correlation between binocular and monocular performance are more conservative because they include any sources of systematic bias, such as those possibly due to a learning effect.

To compare ETDRS acuity with contrast sensitivity as predictors of reading performance, we used receiver operating characteristic (ROC) curves. For each aspect of reading ability, we defined the better eye of an individual as the one with the better performance. When values of CPS and MRS were the same in both eyes, we chose the eye with higher RA. For RA we used CPS as the reference.

Multivariate and univariate regression analyses were performed to determine the joint and unique contribution of ETDRS acuity, contrast sensitivity, and central light sensitivity to reading disability. We used generalized least square random effects regression to take into account correlation between eyes of an individual for continuous dependent variables and a random-effect logit model for dichotomous variables.

Finally, a Cronbach regression model was used to investigate the effect of a predictor on reading within versus between subjects. In this model, the monocular measure of a predictor is used to generate two variables: its difference from the subject mean (eye level) and the difference between the subject mean and the sample mean (subject level). When these two regression coefficients are similar, it can be concluded that the aggregate level—the subject in this type of study—does not influence the relationship between the dependent variable and the predictor.

In the course of all these statistical tests, $P \leq 0.05$ or less was considered to be statistically significant.

Results

Patients’ Characteristics, Visual Psychophysical Evaluations, and Reading Performance

Eighty consecutive patients affected by typical or sine pigmento RP were evaluated. Four of these subjects were either unable to provide measurable ETDRS visual acuity when tested at 1 m or were unable to read any words of the largest sentence of the MNREAD chart at 20 cm. Of the 76 patients studied, 30 were male and 46 female. Mean age was 41 ± 13 (SD) years (range, 15–71). Years of education were 5 or more in all subjects and 10 or more in 28 (37%). Inheritance of RP was autosomal dominant in 10 patients, X-linked in 1 subject, and autosomal recessive or unknown in the others. Diagnosis of RP had been made 10 or fewer years before in 40 (53%) subjects, and 11 to 52 years before in the others.

Visual acuity with the ETDRS charts was 1.0 logMAR (20/200) or less in 14 eyes of 10 patients, among whom 7 eyes in different subjects were unable to read the largest sentence of the MNREAD charts at 20 cm, corresponding to an RA of 1.6 logMAR or less. All the recruited individuals with the exception of three (96%) had an ETDRS acuity of 1.0 logMAR or more in the better eye. Log contrast sensitivity of the better eye was at least 1.0 in 60 (79%) subjects.

RA was 1.0 logMAR or more in the better eye of all patients, excluding six individuals (92%), among whom there were three subjects with a similar level of ETDRS acuity. As expected, the median value of CPS was 0.2 logMAR worse than median RA. CPS was at least 1.0 logMAR in the better eye of 63 patients (85%), but reached a maximum of 0.2 logMAR in only three eyes of two patients. MRS was better than 100 WPM (2.0 logWPM) in the better eye of 59 (78%) subjects. Table 1 shows...
TABLE 1. Distribution of the Main Study Variables

<table>
<thead>
<tr>
<th>Variable</th>
<th>Median</th>
<th>Upper-Lower Quartiles</th>
<th>Maximum-Minimum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Visual acuity (logMAR)</td>
<td>0.32</td>
<td>0.16–0.54</td>
<td>0.00–1.64</td>
</tr>
<tr>
<td>Contrast sensitivity (log units)</td>
<td>1.55</td>
<td>1.80–1.00</td>
<td>2.15–0.05</td>
</tr>
<tr>
<td>Central light sensitivity (dB)</td>
<td>14.90</td>
<td>25.30–8.30</td>
<td>35.00–0.00</td>
</tr>
<tr>
<td>RA (logMAR)</td>
<td>0.56</td>
<td>0.35–0.76</td>
<td>0.00–1.64</td>
</tr>
<tr>
<td>ICPSF (logMAR)</td>
<td>0.70</td>
<td>0.60–0.90</td>
<td>0.20–1.60</td>
</tr>
<tr>
<td>MRS (WPM)</td>
<td>126.00</td>
<td>151.00–85.00</td>
<td>224.00–4.00</td>
</tr>
</tbody>
</table>

The median values, quartiles, and extremes of all the main study variables are summarized. Coefficients for the better and worse eye were similar, as expected in a symmetric disease such as RP. A significant statistical correlation is present between each of the three reading variables and both ETDRS acuity and contrast sensitivity. Retinal light sensitivity was highly related to MRS, especially for points adjacent to fixation, but was moderately associated with RA. Scatterplots of the clinical measures of vision versus RA, CPS, and MRS are presented in Figure 1. Smoothing disclosed a linear relationship between variables, except for a decrease in MRS when retinal light sensitivity close to fixation decreased below 10 dB.

**Clinical Visual Tests as Predictors of Reading Impairment**

Reading impairment, defined as an RA of 0.4 logMAR or worse in the better eye, was found in 47 (62%) subjects. Because all patients without reading impairment were able to read faster than 80 WPM, this definition has also been used to identify the individuals with low reading speed. Figure 2 presents the ROC curves for the ability of ETDRS acuity and contrast sensitivity to predict reading impairment. The area under the curve (AUC) was 0.87 for ETDRS acuity (95% confidence interval [CI]: 0.78–0.96), and 0.88 for contrast sensitivity (95% CI: 0.81–0.95). There was no significant difference between the AUC of ETDRS acuity and contrast sensitivity (P = 0.85). The criterion of ETDRS acuity of 0.3 logMAR (20/40) or worse showed a high sensitivity in detecting reading impairment (89%; 95% CI: 72%–96%), maintaining an acceptable specificity (66%; 95% confidence interval: 46%–78%). The positive and negative likelihood ratios were, respectively, 2.59 and 0.16. A value with similar properties for contrast sensitivity was considered 1.55 log contrast sensitivity or worse, which was recorded in the better eye of 39 (51%) patients, a sensitivity of 94% (95% CI: 82%–99%) and a specificity of 59% (95% CI: 39%–76%). The positive and negative likelihood ratios were, respectively, 2.26 and 0.11.

CPS is an important individual measure in reading rehabilitation, because a patient must be provided as much text magnification as needed to reach the maximum speed. In this RP group, when a value of CPS < 0.2 logMAR in the better eye was used as alternative definition of reading impairment, all except two subjects met this criterion. This fact indicates that a mild to moderate reading impairment is present in most patients with RP.

**Binocular Versus Monocular Reading Performance**

Binocular reading was evaluated in 60 of the 69 subjects who could read with each eye and was compared with that observed in the better eye. There was no difference between them for both RA (median difference: −0.02 logMAR in favor of the better eye, P = 0.15) and CPS (median difference: 0.00 logMAR; P = 0.83). The difference was within ±1 sentence (±0.1 logMAR) in 53 (88%) of 60 individuals for both these measures. Binocular MRS was significantly higher than that registered in the better eye (P = 0.002), but the median difference was only 2% better in WPM. MRS was better binocularly by >25% in only six patients, whereas it was reduced by a similar percentage in one subject. ICCs between binocular and better eye for RA, CPS, and MRS were 0.90 (95% CI: 0.82–0.98), 0.90 (95% CI: 0.79–1.00), and 0.88 (95% CI: 0.79–0.97), respectively.

**Significance of Visual Psychophysical Tests in the Association with Reading Performance**

The strength of the correlations among the reading variables and clinical visual measures was assessed by testing ETDRS acuity, contrast sensitivity, and central light sensitivity in the

TABLE 2. Correlation between Clinical Tests and Reading Performance by Better versus Worse Eye

<table>
<thead>
<tr>
<th>Variable</th>
<th>Better Eye</th>
<th>Worse Eye</th>
<th>Better Eye</th>
<th>Worse Eye</th>
<th>Better Eye</th>
<th>Worse Eye</th>
</tr>
</thead>
<tbody>
<tr>
<td>Visual acuity (logMAR)</td>
<td>0.74**</td>
<td>0.69**</td>
<td>0.67**</td>
<td>0.64**</td>
<td>−0.68**</td>
<td>−0.73**</td>
</tr>
<tr>
<td>Contrast sensitivity (log)</td>
<td>−0.76**</td>
<td>−0.72**</td>
<td>−0.71**</td>
<td>−0.60**</td>
<td>0.81**</td>
<td>0.82**</td>
</tr>
<tr>
<td>Retinal light sensitivity (dB)</td>
<td>−0.48**</td>
<td>−0.45**</td>
<td>−0.34**</td>
<td>−0.29**</td>
<td>0.63**</td>
<td>0.63**</td>
</tr>
<tr>
<td>grand mean</td>
<td>−0.57**</td>
<td>−0.39**</td>
<td>−0.40**</td>
<td>−0.27**</td>
<td>0.64**</td>
<td>0.61**</td>
</tr>
<tr>
<td>0/6°</td>
<td>−0.46**</td>
<td>−0.42**</td>
<td>−0.36**</td>
<td>−0.27**</td>
<td>0.64**</td>
<td>0.66**</td>
</tr>
<tr>
<td>6/12°</td>
<td>−0.45**</td>
<td>−0.46**</td>
<td>−0.32**</td>
<td>−0.32**</td>
<td>0.53**</td>
<td>0.61**</td>
</tr>
<tr>
<td>18/24°</td>
<td>−0.36**</td>
<td>−0.29**</td>
<td>−0.21</td>
<td>−0.19</td>
<td>0.48**</td>
<td>0.44**</td>
</tr>
<tr>
<td>24/50°</td>
<td>−0.44**</td>
<td>−0.27**</td>
<td>−0.26**</td>
<td>−0.25</td>
<td>0.40**</td>
<td>0.41**</td>
</tr>
</tbody>
</table>

Data are Spearman correlation coefficients.

* P < 0.05.

** P < 0.001.
same regression model as covariates. The results are shown in Table 3.

RA independently related to both ETDRS acuity and contrast sensitivity. However, either of the two variables alone was a good predictor of RA, as they respectively accounted for 67% and 63% of the between-subject variance in RA and up to 73% when both were included in the model. Central light sensitivity was not significantly associated with RA in this regression.

CPS was closely associated with ETDRS acuity. In the same model, contrast sensitivity and central light sensitivity were weak but still significant predictors.

The single best predictor of MRS was contrast sensitivity, which alone explained the same amount of between-subject variance in MRS as the multivariate model (70%). Using the percentage of change in WPM as a means of better explaining the coefficients shown in Table 3, MRS declined by 10% WPM for a halving of RA (0.3 log) and contrast sensitivity, and by 11% for a 10-dB decrease in central light sensitivity. In this model, we excluded three eyes of different patients with an MRS of 10 WPM or less after analyses of residuals. Two of these patients were unable to read in the fellow eye. Only central light sensitivity was not significantly associated with RA when these three outliers were maintained in the regression, thus suggesting that it may not be a good predictor of MRS when its values are very low.

The estimates of the regression coefficients and their standard errors did not change when age and years of education were introduced into the models. The only exception was a slight weakening of the association between MRS and ETDRS acuity, which reached only borderline statistical significance when education was also considered.

Role of Predictors at the Eye-Versus-Subject Level

Although RP is considered a symmetrical disease, the eye-level variance accounted for up to half the subject-level variance in a Cronbach regression model.11 This made it possible to investigate whether the association between reading and clinical

FIGURE 1. Scatterplots presenting data and smoothing plot (locally weighted regression) of the three reading performance components versus clinical measures of vision. In these graphs, data from both eyes of all individuals are included. A linear relationship is observed graphically, except for the relationship of CPS and reading speed with light sensitivity. Reading speed dropped noticeably when sensitivity decreased below 10 dB.
predictors is specific to the eye or acts as a unique individual trait. ETDRS acuity was specifically associated with the reading performance of the tested eye. The eye- and subject-level coefficients were similar, regardless of whether the dependent variable was RA (0.527 vs. 0.495, \( P = 0.838 \)) or MRS (0.115 vs. \(-0.102, P = 0.886 \)). On the contrary, most of the association of contrast sensitivity with reading performance was at subject-level for RA (eye vs. subject level: \(-0.092 \) vs. \(-0.366, P = 0.040 \)) and, particularly, MRS (\(-0.073 \) vs. \(0.299, P < 0.001 \)). In other words, even when patients with RP were tested monocularly, contrast sensitivity tended to influence reading as an individual function that is sensitive to visual damage in both eyes and was scarcely associated with the level of damage in the tested eye.

The pattern of central light sensitivity was inconsistent when RA or MRS was the dependent variable. The differences between the eye- and subject-level coefficients did not reach statistical significance in either model. Demographic covariates such as age and years of education did not alter the subject-level effect when introduced together into the analyses.

### Table 3. Multivariate Regression Models of the Association between Reading Variables and Clinical Predictors

<table>
<thead>
<tr>
<th>Dependent Variable</th>
<th>Predictors</th>
<th>Coefficient</th>
<th>95% CI</th>
<th>( P )</th>
</tr>
</thead>
<tbody>
<tr>
<td>RA (logMAR)</td>
<td>ETDRS acuity (logMAR)</td>
<td>0.53</td>
<td>0.37 to 0.69</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td></td>
<td>Contrast sensitivity (log units)</td>
<td>-0.25</td>
<td>-0.36 to -0.13</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td></td>
<td>Constant</td>
<td>0.73</td>
<td>0.52 to 0.95</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>CPS (logMAR)</td>
<td>ETDRS acuity (logMAR)</td>
<td>0.69</td>
<td>0.55 to 0.81</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td></td>
<td>Contrast sensitivity (log units)</td>
<td>-0.14</td>
<td>-0.26 to -0.01</td>
<td>0.041</td>
</tr>
<tr>
<td></td>
<td>Central light sensitivity (per 10 dB)</td>
<td>0.05</td>
<td>0 to 0.09</td>
<td>0.035</td>
</tr>
<tr>
<td></td>
<td>Constant</td>
<td>0.66</td>
<td>0.44 to 0.88</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>MRS (logWPM)</td>
<td>ETDRS acuity (logMAR)</td>
<td>-0.15</td>
<td>-0.25 to -0.04</td>
<td>0.007</td>
</tr>
<tr>
<td></td>
<td>Contrast sensitivity (log units)</td>
<td>0.16</td>
<td>0.24 to 0.08</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td></td>
<td>Central light sensitivity (per 10 dB)</td>
<td>0.05</td>
<td>0.03 to 0.08</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td></td>
<td>Constant</td>
<td>1.77</td>
<td>1.62 to 1.93</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

CI, confidence interval.
RP involves a progressive visual loss—earlier reducing personal autonomy in orientation and mobility and later other visual performance, such as reading. Recently, West et al.\textsuperscript{12} performed a population-based, cross-sectional study on the effect of visual loss related to any type of disease in tasks of everyday life. Mobility is substantially impaired at visual acuity \(<1.0\) logMAR (20/200). For highly demanding visual tasks, such as reading, visual acuity \(<0.2\) logMAR (20/50) or contrast sensitivity \(<1.4\) log units were disabling. At these levels of visual performance, at least 50% of the population are in the disabled range, defined as reading \(<90\) WPM. The essentially linear relationship between visual loss and functional loss in tasks led investigators to conclude that there is no optimal cutoff point for visual acuity and contrast sensitivity, both of which are highly sensitive and highly specific.\textsuperscript{12} These observations agree with our findings in the present study in patients with RP who were assessed with a standard reading test. Other reports regarding patients with RP have described the correlation of vision clinical measures with performance in tasks resembling those of daily life,\textsuperscript{2,13} as well as with self-reported activity.\textsuperscript{2,3,14} In the investigation performed by Szlyk et al.,\textsuperscript{2} objective performance in several reading tasks was rated by an orientation and mobility instructor, and a questionnaire was used for self-reported performance. Correlation coefficients of ETDRS acuity, contrast sensitivity, and visual field area with Goldmann perimetry were in the range of those observed in this study for RA, with visual field scores yielding a lower correlation than the other two tests. In a study using questionnaires, Sumi et al.\textsuperscript{3} have observed that mean sensitivity within the central \(10^\circ\), as assessed with the Humphrey central 30-2 program (Carl Zeiss Meditec), has a higher correlation with reading performance than that of more peripheral areas, as was found by us.

The strength of the present study is an objective reading test, the MNREAD charts, that allows continuous measurement of selected reading components, specifically those related to acuity (RA and CPS) and MRS, which is reached when print size is not a limiting factor. Measurement of MRS is often impossible with a test resembling an everyday reading task, such as reading a newspaper, because it is based on a specific and small print size that cannot be read by many subjects with low vision. A previous publication found that the MNREAD rate closely correlates with the rate of reading other materials for consumers with low-vision who had already been prescribed magnifiers and had used them for between 3 months and 21 years.\textsuperscript{15}

As found in previous studies of patients with low-vision due to various diseases,\textsuperscript{16–18} visual acuity and contrast sensitivity were predictors of reading performance in patients affected by RP. Reduced central retinal light sensitivity was associated with a lower MRS, regardless of visual acuity. When sensitivity was \(<10\) dB, many patients also had a decreased reading rate due to large print size and so, as discussed in detail later in this section, depressed central light sensitivity may affect reading rehabilitation potential in patients with more advanced RP.

A Cronbach model\textsuperscript{11} was a useful means of evaluating the pattern of the association between the clinical psychophysical tests and reading. In patients with RP, ETDRS acuity is an eye-specific predictor, whereas CS is an individual trait determined by the type of loss in both eyes. These findings were consistently obtained in relation to both RA and MRS, which are different components of reading activity.

Having measured the reading performance of patients with RP of different degrees of severity, the study may help delineate their potential for rehabilitation. RA was an average of 0.2 logMAR (two MNREAD sentences), similarly worse than the corresponding logMAR of ETDRS acuity and better than the CPS. However, the residual variability of the observations around their estimate prevented the use of even multivariate models to predict the individual need for rehabilitation. A more practical approach was to define moderate-severe reading im-

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**DISCUSSION**

**Relationship between Visual Field Constriction and Reading Impairment**

On the basis of the criterion defined in the Methods section, 30 (21%) eyes of 25 subjects with RP had a significant limitation of reading speed with large print size. The odds ratio (OR) for having such a limitation was 3.6 for a 10-dB reduction in central light sensitivity (95% CI: 1.8–7.2, \(P < 0.001\)) regardless of ETDRS acuity, which did not reach statistical significance in this model or substantially alter this estimate. Figure 3 shows the probability of such a limitation as predicted by central light sensitivity in this logistic regression model. Most of the eyes with a central light sensitivity of 10 dB or less had a predicted 20% to 60% probability of having decreased reading speed with large print size. When the cutoff point of 10 dB was used to transform central light sensitivity into a dichotomous variable, the OR for a decline in reading speed due to larger print size was 14.1 (95% CI: 3.5–7.2, \(P < 0.001\)) regardless of age, ETDRS acuity, contrast sensitivity, and visual field area.14–16-17 These observations agree with previous studies of patients with low-vision due to various diseases,2,10–15 visual acuity and contrast sensitivity were predictors of reading performance in patients affected by RP. Reduced central retinal light sensitivity was associated with a lower MRS, regardless of visual acuity. When sensitivity was \(<10\) dB, many patients also had a decreased reading rate due to large print size and so, as discussed in detail later in this section, depressed central light sensitivity may affect reading rehabilitation potential in patients with more advanced RP.

![Figure 3](image-url) - Probability of a limitation in reading speed due to larger print size, as predicted by central retinal light sensitivity in a logistic regression model, including visual acuity as a covariate. Most of the eyes with a light sensitivity of \(<10\) dB showed a slower reading speed when print size increased to a certain level.
performance as an RA of 0.4 logMAR or less, roughly equal to the inability to read ordinary print at 40 cm with any speed, which could be detected with 90% sensitivity by a visual acuity of 0.3 logMAR or less. The Salisbury Eye Evaluation (SEE) project found that this cutoff point was similarly sensitive in identifying a lower reading speed in a population-based sample.\textsuperscript{12} CPS is the most meaningful measure for reading rehabilitation, although the MNREAD measures it more discretely than RA and so it may be more prone to misclassification in clinical research. It was suboptimal in almost all our subjects, which indicates the need to assess reading performance in patients with RP, regardless of their visual acuity, especially if they have no accommodative reserve. Nonetheless, the rehabilitation potential of patients with RP is usually expected to be good. Although CPS was often reduced, it was 1.0 logMAR or more in the better eye of most of the subjects, which means that most of them will achieve their MRS with a slight magnification of typically two or three times. Moreover, MRS was sufficiently high in most patients.

In contrast, visual field constriction can be expected to limit the possibility of using high magnification in patients with more severe reading impairment. A mean central light sensitivity <10 dB was commonly associated with a decline of reading speed for print size larger than 1.0 to 1.3 logMAR, corresponding to 40 to 80 Times New Roman characters viewed at 40 cm. Therefore, the potential for magnifier-aided reading rehabilitation in such individuals may be limited, confirming the impression described by low-vision rehabilitators in clinical practice.\textsuperscript{19} This item could not be fully characterized because the range of print size allowed in the present study was limited by the decision to adopt fixed viewing distances to standardize evaluation.

The number of years since RP diagnosis was a strong negative predictor of both RA and MRS, given similar levels of clinical measures of vision. The explanation of this result could be twofold. First, because few subjects in this select RP group had undergone reading rehabilitation, the reading mechanism may have been impaired by a long-standing inability to perform this task. Alternatively, time from diagnosis may be a surrogate for unconsidered psychophysical functions that are partly unrelated to common clinical measures.

The possibility of generalizing the results of a study mainly depends on the profile of the enrolled population. Nearly 50% of patients with RP in this study had an ETDRS visual acuity of 20/40 or more in the better eye, a percentage similar to that documented by Grover et al.\textsuperscript{20} in a clinic-based series of almost 1000 patients. Because only seven (9%) subjects of our RP series presented an ETDRS acuity lower than 20/200, the performance of patients with so severe a central visual loss, which had a higher incidence within the series of Grover et al. (25%).\textsuperscript{20} cannot be exactly assessed. In this series, persons with this type of vision impairment were completely unable to read or had very poor reading performance. As mentioned earlier, the reduction of reading speed associated with visual field restriction supports the clinical observation of substantial difficulty in rehabilitating these patients with optical low-vision aids.\textsuperscript{19} In fact, patients with RP often need a slight magnification and enhanced contrast, and visual rehabilitation should be designed to improve their pursuit and scanning strategies to optimize reading speed and ability to navigate the text.

Because the patients in this study were native Italians, the generalizability of its results implies the assumption that the underlying psychophysical phenomena are similar in populations speaking different languages based on the same alphabet. Appropriate studies are needed to demonstrate this hypothesis.

In conclusion, the reading performance of patients affected by RP was mildly to moderately impaired in this relatively large, multicenter study of patients with different degrees of disease severity. The results suggest that reading should always be assessed in people with RP, because a variable degree of reading disability is common regardless of visual acuity.

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**References**


