Reading Ability and Reading Engagement in Older Adults With Glaucoma

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PURPOSE. We evaluated the impact of glaucoma-related vision loss on reading ability and reading engagement in 10 reading activities.

METHODS. A total of 63 glaucoma patients and 59 glaucoma suspect controls self-rated their level of reading difficulty for 10 reading items, and responses were analyzed using Rasch analysis to determine reading ability. Reading engagement was assessed by asking subjects to report the number of days per week they engaged in each reading activity. Reading restriction was determined as a decrement in engagement.

RESULTS. Glaucoma subjects more often described greater reading difficulty than controls for all tasks except puzzles (P < 0.05). The most difficult reading tasks involved puzzles, books, and finances, while the least difficult reading tasks involved notes, bills, and mail. In multivariable weighted least squares regression models of Rasch-estimated person measures of reading ability, less reading ability was found for glaucoma patients compared to controls (β = −1.60 logits, P < 0.001). Among glaucoma patients, less reading ability was associated with more severe visual field (VF) loss (β = −0.68 logits per 5-dB decrement in better-eye VF mean deviation [MD], P < 0.001) and contrast sensitivity (β = −0.76 logits per 0.1-unit lower log CS, P < 0.001). Each 5-dB decrement in the better-eye VF MD was associated with book reading on 18% fewer days (P = 0.003) and newspaper reading on 10% fewer days (P = 0.008). No statistically significant reading restriction was observed for other reading activities (P > 0.05).

CONCLUSIONS. Glaucoma patients have less reading ability and engage less in a variety of different reading activities, particularly those requiring sustained reading. Future work should evaluate the mechanisms underlying reading disability in glaucoma to determine how patients can maintain reading ability and engagement.

Keywords: glaucoma, reading, quality of life, low vision

Patients with low vision most often identify reading difficulty as their greatest vision-related concern and primary reason for seeking low vision services.1 Because reading is necessary for performing many daily tasks and achieving a number of common societal objectives (i.e., daily living, social interaction, recreation, and work), reading difficulty can cause substantial disability (defined as reduced ability compared to the norm to perform reading tasks that are important to an individual), and can be detrimental to quality of life (QOL).2–5

Previous studies that have evaluated reading in subjects with visual impairment almost exclusively have attributed reading disability to visual acuity (VA) loss due to refractive error, cataract, or macular disease.6–8 Therefore, there exists a common assumption (backed by some evidence) that reading is not affected in diseases of peripheral vision loss, such as glaucoma, especially when VA is normal.9 However, a few recent studies have suggested that glaucoma is associated with greater self-reported reading difficulty, and a recent paper has demonstrated modestly lower reading speeds in patients with glaucoma.3,5,10–13

These prior studies of reading in persons with glaucoma, however, were limited in their capacity to assess reading disability for a few reasons. First, most studies have been concerned more broadly with the impact of vision loss on overall QOL rather than specific effects on reading. Therefore, such works have lacked the proper instrumentation to evaluate reading alone. For example, the 25-item National Eye Institute Visual Function Questionnaire (NEI VFQ-25), which was developed by Mangione et al.11 to study the influence of vision impairment on QOL, contains only one item related to reading. Additionally, prior studies have used questions measured on a Likert-scale, which is flawed in its approach to measuring latent variables, such as reading ability.14 Finally, prior studies have not ventured to determine whether engagement in reading is impacted by glaucomatous vision loss.

Characterizing reading ability and reading engagement in patients with glaucoma would help us better understand how glaucoma disables individuals with the disease and better determine the best methods for enabling reading in patients with glaucoma. We sought to test the hypothesis that reading...
ability and engagement are less with more severe glaucoma-
tous vision loss. Reading ability was judged by a subject’s
assessment of reading difficulty (i.e., the perceived difference
between one’s reading ability [a latent person trait] and the
reading ability required to perform a certain reading task) using
Rasch analysis.

METHODS
The study protocol adhered to the tenets set forth by the
Declaration of Helsinki, and all study procedures were
approved by the Institutional Review Board of Johns Hopkins
Hospital. Subjects were recruited for a broader study
involving tests of reading speed as was previously published.13
Subjects for the control group were included in the study if
they were at least 50 years old, had a chart diagnosis of
primary open angle glaucoma, had a presentations VA of 20/40
or better in both eyes, and had right and left eye visual fields
(VF) meeting the following criteria: mean deviation (MD) better
than −3 dB in at least one eye and better than −4 dB in both
eyes on a Swedish Interactive Thresholding Algorithm
(SITA) standard Humphrey 24-2 visual field test, and a
glaucoma hemifield test (GHT) result of “within normal limits,”
“borderline,” or “general reduction of sensitivity.”
Subjects for the glaucoma group were included in the study if
they were at least 50 years old, had a chart diagnosis of
primary open angle glaucoma, primary angle closure glauco-
ma, pseudoxfoliation glaucoma, or pigment dispersion
glaucoma, had a presenting VA of 20/40 or better in at least
one eye, and had right and left eye VFs meeting the following
criteria: MD worse than −3 dB in the better-eye and a GHT
result of “outside normal limits,” “generalized reduction of
sensitivity,” or “borderline.”
Potential subjects in both groups were excluded if they had
a VA worse than 20/40 in the better-seeing eye or had vision
loss secondary to another eye condition, were illiterate by self-
report, or had any laser procedure in the previous week or any
ocular surgery in the previous 2 weeks. Based on prior
research demonstrating that better-eye and integrated VF MD
rarely differ and do not predict visual disability differently, VF
severity was defined as the higher (less negative) MD between
the 2 eyes taken from SITA standard 24-2 fields.15 All enrolled
subjects participated in the same testing measures that are
described below as well as tests of reading speed, which were
analyzed in a separate study.13

Measurement of Reading Ability
Reading ability and reading engagement were assessed using
a questionnaire administered orally to subjects during an
in-person interview containing 10 different reading items:
periodicals, newspaper articles, bills, financial statements,
handheld menus, religious texts, books, word puzzles, typed
mail, and written notes or mail. The 10 reading items used in
our questionnaire were taken from the Activity Inventory (AI),
a visual function questionnaire developed and validated by
Massof et al.16 to measure visual ability in patients with low
vision. The 10 AI reading tasks were chosen to provide enough
breadth and variety to cover the varying levels of reading ability
among our subjects. For each activity, subjects first were asked
how important the activity was to them. The importance
response categories were: “not important,” “somewhat
important,” “moderately important,” and “very important.”
If the subject responded “not important,” then the interviewer
moved on to the next task. If the task was rated with any other
importance category, then the subject was asked to rate the
difficulty of that reading task without the assistance of another
person. The difficulty response categories were: “not difficult,”
“slightly difficult,” “moderately difficult,” “very difficult,”
“extremely difficult,” and “impossible.” Based on a previous
Rasch analysis of the six rating categories used by a large
sample of low vision patients,16 we merged two categories and
assigned rank scores to the response categories as follows: 3,
“not difficult”; 2, “slightly or moderately difficult”; 1, “very
or extremely difficult”; and 0, “impossible.” When participants
were asked to rate the difficulty of these reading tasks, they
were assigning a rating to the magnitude of the difference
between their reading ability and the ability level required by
the task. Therefore, reading ability is a function of the difficulty
ratings assigned to a series of different reading tasks, which
was estimated by the Rasch analytical model.
Reading engagement was defined as the rate at which
participants engaged in a particular reading activity in an
average week. To evaluate reading engagement, subjects were
asked to state how many days out of a typical week they
perform each of the 10 reading activities that they deemed to
be at least slightly important.

Measurement of Vision and Covariates
The VA was measured under binocular conditions with charts
developed for the ETDRS.17 The VA was scored as the total
number of letters read correctly and converted to the
logMAR according to the method described previously.18 The VF MD
was measured with the SITA standard 24-2 VF testing
performed on a Humphrey Field Analyzer 2 (Carl Zeiss
Meditec, Inc., Dublin, CA, USA). Contrast sensitivity (CS) was
measured under binocular conditions as the number of letters
read correctly on the Pelli-Robson chart and converted to a log
scale (logCS).19 Lenticular changes, including nuclear sclerotic,
cortical, and posterior subcapsular changes, as well as
posterior capsular opacification (PCO), were graded as present
or absent as described previously.20
Since several nonvisual age-related factors may decrease a
person’s ability to read with increasing age, such as decreased
cognitive ability and depression,20–22 cognitive ability and
depressive symptoms were measured in our subjects along
with other general health-related variables. Cognitive ability
was evaluated using the Mini-Mental State Exam (MMSE).23 The
presence of depressive symptoms was assessed using part D of
the General Health Questionnaire by Goldberg et al.,24 with a
positive response to any question taken to indicate the
presence of depressive symptoms. Sociodemographic vari-
ables, including age, race, education, and employment, were
gathered using standardized questionnaires.

Statistical Methods and Programming
Group differences in demographic, health, and vision charac-
teristics were analyzed using the Student’s t-test for normally-
distributed continuous variables and χ² test for categorical
variables.

Statistical Analyses of Reading Difficulty. Rasch analysis
was performed using Winsteps (Winsteps, Chicago, IL, USA) to
estimate linear item measures for each reading task and linear
person measures for each subject based upon their responses to the individual reading difficulty questions. Person measures were taken to be a measure of overall reading ability. Item measures and person measures were expressed in logits along the same scale. The zero value of the scale was defined as the mean of the item measures. Higher item measures corresponded to greater reading difficulty for the item. Higher person measures (indicating greater reading ability) corresponded to being able to perform more difficult reading tasks without difficulty. The item measures were anchored to item measures determined from a separate, larger cohort of glaucoma subjects seen at low vision clinics (n=212) who were asked the same questions about reading difficulty.25 Analysis of differential item function (DIF) with the Mantel-Haenszel method was used to investigate each item for signs of dependencies on patient item function (DIF) with the Mantel-Haenszel method was used to evaluate the fit of the data to the expectations of the Rasch measurement model. The distributions of item measures and person measures were expressed in logits along a certain reading task were evaluated in separate weighted least squares regression models for controls and glaucoma subjects using the Rasch-derived person measures (in logits) as the dependent variable, adjusting for age, sex, race, educational level, and cognitive ability. Outcomes were expressed as a rate ratio (RR), reflecting the ratio of days in which the reading task would be performed in two subjects with a 5-dB difference in their better-eye VF MD.

Analyses were performed using STATA 12 (STATA, College Station, TX, USA). Covariates were included in multivariable weighted least squares regression and negative binomial regression models if they were statistically significantly (P < 0.05) associated with the outcome of interest in univariable models.

**RESULTS**

**Description of Patients**

A total of 59 glaucoma suspect controls and 63 glaucoma subjects completed all study procedures. Glaucoma subjects were older than controls (71.6 vs. 67.0 years, P < 0.01), but did not differ with regard to demographic or general health-related variables (Table 1). Compared to controls, glaucoma subjects had greater VF loss on reading restriction (defined as the decreased frequency of engagement in certain reading tasks) was analyzed using a negative binomial regression model controlling for age, sex, race, educational level, and cognitive ability. Outcomes were expressed as a rate ratio (RR), reflecting the ratio of days in which the reading task would be performed in two subjects with a 5-dB difference in their better-eye VF MD.

**Statistical Analyses of Reading Engagement.** The effect of greater VF loss on reading restriction (defined as the decreased frequency of engagement in certain reading tasks) was analyzed using a negative binomial regression model controlling for age, sex, race, educational level, and cognitive ability. Outcomes were expressed as a rate ratio (RR), reflecting the ratio of days in which the reading task would be performed in two subjects with a 5-dB difference in their better-eye VF MD.

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are shown in Figure 2. Item and person measure separation reliabilities were 0.88 and 0.78, respectively, indicating that 88% and 78% of the variance in item and person measures were attributable to true differences in the items or people, and not estimation error. The DIF analysis showed that each of the items functions similarly for glaucoma subjects and control subjects, with no statistically significant differences in the way any of the items functioned except for religious texts ($P > 0.1$ for all items except religious texts). In determining the validity of applying the Rasch model, infit mean square residuals for each item measure were calculated, and they all fell within ±2 SDs of the expected value, except for puzzles (>3 SDs). The misfit of puzzles to the model may be due to the infrequency with which subjects deemed puzzles to be important or due to individual variations in the interpretation of the term, “puzzles.”

FIGURE 1. Percentage of glaucoma and control subjects reporting difficulty for each of 10 different reading tasks. Responses were partitioned into three categories of difficulty: no difficulty (not shown), mild difficulty, and moderate-to-severe difficulty.

FIGURE 2. Distribution of reading ability from Rasch-estimated item measure and person measure scores (logits) mapped onto the same scale. Higher person measure scores indicate less reading ability in the individual. Higher item measure scores indicate less difficulty associated with the particular task. Item measure scores are found at the midpoint of the transition point from no difficulty to severe difficulty.

FIGURE 3. Box-whiskers plots of Rasch-estimated person measure score (logits) of control and glaucoma subjects, showing the 25th and 75th percentile range (box) and median values (transverse lines in the box).

Predictors of Overall Reading Disability Based on Rasch Outcomes

Subjects with glaucoma and control subjects differed in their distribution of overall reading disability as defined by their person measures (Fig. 3, Glass’s $\Delta = 1.13$, $P < 0.001$).

In a weighted least squares regression model, subjects with glaucoma had significantly lower reading ability than control subjects ($\beta = -1.60$ logits, 95% CI $= -2.54$ to $-0.66$, $P < 0.001$, Table 2). In weighted least squares regression models of only glaucoma subjects, lower reading ability is associated with greater VF loss ($\beta = -0.68$ logits per 5-dB decrement in the better-eye VF MD, 95% CI $= -1.03$ to $-0.33$, $P < 0.001$) and lower CS ($\beta = -0.48$ logits per 0.1-unit lower binocular log CS, 95% CI $= -0.76$ to $-0.20$, $P < 0.001$). Worse VA was associated with less reading ability, but this association was not statistically significant ($\beta = -0.17$ logits per 0.1-logMAR increment, 95% CI $= -0.59$ to $-0.24$, $P = 0.41$). In multivariable models, African American subjects were less likely to have less reading ability compared to non-African American subjects, while subjects with lower educational attainment or depressive symptoms were more likely to have less reading ability. The presence of a visually-significant cataract or PCO in either eye was not a significant predictor of reading ability in multivariable models. No variable (visual or nonvisual) demonstrated a significant association with reading ability in models only containing control subjects.
Self-Reported Engagement With Specific Reading Tasks

After controlling for age, sex, race, cognition, and education level, each 5-dB decrement in better-eye VF MD was associated with reading books on 18% fewer days (CI = 6%–28%, \( P = 0.003 \)) and newspapers on 10% fewer days (CI = 3%–17%, \( P = 0.008 \), Fig. 4). Significant reading restriction with greater VF loss was not noted for any other reading tasks (\( P > 0.05 \) for all except books and newspapers).

**DISCUSSION**

Having glaucoma makes reading more difficult across a broad range of reading tasks, and overall reading disability (as judged by Rasch-estimated reading ability person measures) is significantly affected by glaucoma. Patients with glaucoma also are more likely to avoid reading, with a trend showing that there is greater restriction of tasks involving sustained reading, such as books and newspapers. These findings are based upon a 10-item instrument, which was judged to be valid and reliable based upon high person and item measure reliability indices, the absence of significant DIF for 9 of 10 tasks, and the absence of misfitting items (with the exception of puzzles). Novel features of this study include the use of a Rasch measurement model for ordering task difficulty, the use of the Rasch model to measure overall reading ability, and the assessment of reading engagement in glaucoma. Central VA was well-preserved in the studied cohort, further reinforcing the concept that glaucomatous VF loss and CS loss can impair reading even in the presence of relatively normal VA.

Our findings support prior studies of reading disability in subjects with glaucoma which, through performance testing, have demonstrated that reading function is poorer in subjects with glaucoma. For example, Altevergel et al.\(^\text{12}\) tested the performance of glaucoma patients on a series of vision-related activities and identified reading small print as one of the tasks causing greatest difficulty among glaucoma patients. Similarly, using performance-based measures, Richman et al.\(^\text{30}\) found a significant correlation between binocular VF loss, CS, and VA, and reading in reduced illumination. Recent work has demonstrated that glaucoma is associated with decreased reading speed, particularly when reading is evaluated through sustained silent reading (as opposed to short-duration out-loud reading) and when individuals are asked to read low-contrast materials.\(^\text{13}\) While performance-based measures, such as those in prior works, can be made precisely and accurately, they typically are measured in tightly-controlled conditions, which may not fully reflect an individual patient’s native environment.\(^\text{31,32}\) Additionally, performance-based testing does not elicit information about how well a respondent thinks he or she reads, which is information that more directly exemplifies the functional consequences of visual impairments. Therefore, we believe that self-rating of difficulty importantly assesses the individual’s perception of functionality, which is a critical component of quality of life.

The findings of this current study also support the conclusions made from prior studies assessing reading disability using questionnaires or focus groups, which have found that over 40% of patients with glaucoma report problems with reading small print.\(^\text{4,10}\) However, these works evaluated reading only with a small number of questions imbedded within a larger questionnaire, and they did not have a proper instrument to measure disability properly in glaucoma subjects compared to control subjects. The present study added rigor to this previous work by using a validated Rasch analytical method to determine that overall reading disability is associated with glaucomatous vision loss. Our work also provided new evidence that different types of reading tasks can be affected differently by glaucoma.

Reading disability and reading restriction in patients with glaucoma may result from a number of mechanisms, including aberrant eye movements from VF defects, poorer detection of low contrast stimuli, poor acuity reserve, or inadequate lighting conditions. Data indicate that greater VF loss is...
associated with difficulty in finding the next line of text.\textsuperscript{33} Fewer saccades have been noted among patients with VF defects during various tasks, raising the possibility that abnormal eye movements may mediate reading impairment in glaucoma.\textsuperscript{34-37} Decreased CS also may mediate the impact of glaucoma on reading. Indeed, recent work found that patients with glaucoma are more challenged by decreased letter contrast than normally-sighted individuals.\textsuperscript{38} Glaucoma patients have worse distance- and near-vision, CS, and CS with glare when measured at home versus in the clinic, suggesting that CS in the native environment may be sufficiently low as to impair reading.\textsuperscript{39} Glaucma patients may experience reading fatigue as a result of the exertion needed to overcome the above-mentioned visual and environmental factors, and low vision services should seek to address these factors to facilitate prolonged reading.

While reading is a common complaint among glaucoma patients,\textsuperscript{1} only a small percentage of glaucoma patients are referred to rehabilitative services. One barrier to referrals may be the fact that physicians may not view glaucoma patients as requiring visual rehabilitation services, as they most often refer patients with central vision deficits. An additional barrier to referral may be that glaucoma patients often do not express severe reading difficulty to the extent that reading would be impossible. Finally, rehabilitative services, including efforts to enable glaucoma patients to tailor their reading environment, are rarely referred to serve patients with central vision loss and those with VF loss.\textsuperscript{40} Additional work is necessary to define the best methods for enabling reading in patients with glaucoma, perhaps by creating proper lighting to optimize contrast and reduce glare, correcting aberrant eye movements, using visual aids to enlarge text, and/or teaching strategies to mitigate fatigue.\textsuperscript{39,41-45}

One limitation of our study is that a large number of patients were at or near the maximum possible ability measure that could be estimated from our reading items because they responded “not difficult” to all of the queried tasks. We addressed this limitation by using weighted logistic regression to reduce the contributions of those who were at the extreme end of the scale, though future studies should consider adding more difficult items to extend the scale and more precisely estimate person measures scores in these individuals. Obtaining a greater number of subjects in future studies would be beneficial to resolve more precisely the magnitude of the association between VF loss and CS on reading disability, given the large confidence intervals (CI) surrounding those measures obtained in our study. While our study was able to comment on reading engagement, questioning subjects about the number of days they perform a task does not allow us to know precisely how much time is spent performing a certain task. To quantify reading engagement more accurately, future studies may take advantage of increasingly popular electronic-based reading technology to record time spent performing certain reading tasks more accurately. Finally, while reading disability and reading restriction were considered as independent outcomes here, further work is needed to determine whether they are indeed independent, or whether both decline together as vision declines.

In summary, individuals with glaucoma experience greater reading disability than individuals with normal vision, as evidenced by the greater levels of reading difficulty and restriction of specific reading tasks. Sustained reading tasks may be affected particularly by glaucoma, but further studies will be needed to confirm these findings. Given the importance of reading to performing numerous daily tasks and meeting many societal objectives, further work is necessary to define methods to optimize reading in this group of patients.

**References**


