



# Comparison of Reading Test Parameters from the Print and Tablet Application Forms of the Minnesota Low Vision Reading Test

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## Abstract

**Objectives:** To compare reading parameters measured with the Turkish version of the Minnesota Low Vision Reading Test (MNREAD-TR) printed acuity chart and the tablet application version of the same test for both normally sighted and low-vision individuals.

**Materials and Methods:** A total of 116 individuals (92 normally sighted and 24 low-vision) were included in the study. All participants were tested with both the print version of the MNREAD-TR chart (method 1) and the tablet application version (method 2). Reading acuity (RA), critical print size (CPS), maximum reading speed (MRS), and reading accessibility index (ACC) were compared statistically.

**Results:** No statistically significant difference was found in RA and CPS between the two methods for the normally sighted individuals ( $p=0.083$  and  $p=0.075$ , respectively). There was no statistically significant difference in RA and ACC between the two methods for the patients with low vision ( $p=0.159$  and  $p=0.103$ , respectively). The mean MRS was  $233.1 \pm 34.7$  words per minute (wpm) with method 1 and  $169.3 \pm 23.4$  wpm with method 2 in the normally sighted group ( $p<0.001$ ) and  $93.2 \pm 50.2$  wpm with method 1 and  $68.2 \pm 34.7$  wpm with method 2 in the low-vision group ( $p<0.001$ ).

**Conclusion:** In our study, it was found that the parameters RA and CPS in the normally sighted individuals and RA and ACC in the low vision individuals provided similar results in both forms of the MNREAD. The tablet application method can be preferred to eliminate evaluators' bias of scoring the printed chart. In addition, applications have other advantages such as being faster and more practical and providing automatic analysis of parameters, especially in low-vision rehabilitation.

**Keywords:** Low vision rehabilitation, MNREAD, near vision examination, reading acuity, reading speed

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## Introduction

Reading ability is a strong determinant of quality of life.<sup>1,2,3</sup> According to the results of the Wilmer Eye Institute Vision Rehabilitation Department, the chief complaint in 64% of all low-vision patients is reading difficulty.<sup>4</sup> Therefore, it is crucial to measure reading performance in low-vision individuals. Minnesota Low Vision Reading (MNREAD) acuity charts are text-based charts used to assess near vision and reading speed in individuals with normally sighted and low vision.<sup>5</sup>

Several versions of the MNREAD acuity charts have been prepared in various languages.<sup>6</sup> The Turkish version (MNREAD-TR) was created by Idil et al.<sup>7</sup> MNREAD acuity charts are widely used in evaluating reading ability.<sup>8</sup> However, the examiner is responsible for counting errors, calculating MNREAD parameters, and timing reading speed, leading to potential scoring subjectivity and detection bias. Standardization is necessary to achieve objective and repeatable measurements, especially for individuals with low vision.<sup>9,10,11</sup> Technological developments have provided promising opportunities to solve such problems. For instance, the use of tablets for medical screening tests has drawn interest to digital reading.<sup>12,13</sup> The ease of access to tablets created an opportunity to perform MNREAD tests with an iPad application. An MNREAD iPad application has been introduced for clinical use to standardize the measurement of reading parameters and make the test more practical.<sup>9,14</sup> Calabrèse et al.<sup>14</sup> created a digital version of the MNREAD charts to be used with the MNREAD iPad App ©2017. They compared MNREAD parameters from the printed acuity chart and the iPad application and reported similar results for both methods in normally sighted and low-vision individuals. They concluded that the MNREAD application would be useful for the standardization of the results.

In this study, we aimed to evaluate whether the consistency between the MNREAD chart and MNREAD iPad application previously reported for the original form also exists in different language versions. For this purpose, we planned to conduct a similar study for the MNREAD-TR in normally sighted and low-vision individuals. The findings of this evaluation will help us determine whether we can use the tablet application, which seems to be a more practical method, instead of the conventional printed method for the assessment of reading parameters in patients presenting to low vision rehabilitation centers.

## Materials and Methods

The study included a total of 116 participants, 92 normally sighted and 24 low-vision individuals, and was carried out in the Ankara University Faculty of Medicine Vision Research and Low Vision Rehabilitation Center. All participants were tested with both the printed form of the MNREAD-TR chart and the tablet application form (MNREAD iPad App ©2017) and the MNREAD parameter results obtained with the two methods were compared. Participants in the normally sighted group

had visual acuity of 0.00 logMAR with or without refractive correction and had no reported cognitive or reading impairment. Participants in the low-vision group had various diagnoses and visual acuity levels but no cognitive impairment or reading deficit diagnosis reported in previous examinations. The native language of all participants was Turkish. Ethics committee approval was received before study initiation and participant enrollment. An informed consent form was obtained from all participants. The study was conducted in accordance with the Helsinki Declaration.

In the printed form of MNREAD, there are 19 sentences with print sizes ranging from 8 M to 0.12 M (according to the M unit, 1 M=8 points), corresponding to a largest print size of 1.3 logMAR and smallest print size of -0.5 logMAR. Each sentence consists of 60 characters and the print size decreases by 0.1 logMAR with each consecutive sentence. The values on the chart are adjusted for a viewing distance of 40 cm. However, for those with low vision, there is a correction table that enables testing at varying distances. The cards have white-on-black and black-on-white polarities. This study used the MNREAD-TR, and four parameters of reading performance were assessed. The first three parameters were reading acuity (RA; the smallest print size that can be read without making a significant mistake), critical print size (CPS; the smallest print size that can be read with maximum reading speed), and maximum reading speed (MRS; reading speed irrespective of print size).<sup>5</sup> Reading accessibility index (ACC) is a new parameter defined in 2016.<sup>15</sup> ACC is calculated by dividing the reading speed obtained in the first 10 sentences of the MNREAD chart by 200. These sentences represent the most frequently used print sizes in daily life. As normal reading speed corresponds to 200 wpm, the normal ACC value is 1. This parameter represents the visual accessibility of commonly encountered printed material, where 0 means no accessible print and 1 means average normal accessibility.<sup>15,16,17</sup> With the printed form, the practitioner records reading time, number of errors, and reading distance. Therefore, the examiner is responsible for calculating the four MNREAD parameters.

The MNREAD tablet application developed for the iPad by the University of Minnesota also includes a Turkish version. For the print and tablet application forms, different sentences meeting the standard guidelines were chosen from a previously prepared sentence pool. This application can be run on third-generation or later iPads and requires a minimum of iOS 7.0 operating system (<http://www.precision-vision.com/product/mnreadchart1>). For now, the tablet form of MNREAD is only available on iOS operating systems while the MNREAD Android application is still in development.

To assess the performance of the MNREAD iPad application in routine clinical practice, two questions need to be answered: Are automatic results obtained from the MNREAD iPad application consistent with those obtained from the printed MNREAD chart? What can be done for problems caused by screen size and screen resolution? For the second question,

Calabrèse et al.<sup>14</sup> suggested changing the reading distance and reducing the number of sentences in the test to solve these limitations with the iPad app. Due to screen size and resolution limitations in the tablet method, the first sentence and the last 4 sentences were removed and a total of 14 sentences were used.<sup>14</sup> Print sizes are between 1.2 and -0.1 logMAR (6.3M-0.32M). For each presentation, a sentence from the pool prepared for MNREAD is selected and displayed centered on the screen in Times New Roman font (Figure 1).

With normally sighted participants, the printed MNREAD chart was tested at a distance of 40 cm. For the tablet application method, the test distance was extended to 80 cm to compensate for the smaller print size range.<sup>14</sup> The individuals with low vision were tested at their preferred distance for both methods and the reading distance was recorded. In both groups, the preferred distance was adjusted according to the 4<sup>th</sup> largest print size.<sup>14</sup> The test was done with black-on-white polarity for both methods. All participants underwent a near vision examination before the test. Different sentence sets were used for the chart and the application to eliminate the bias of participants' remembering the sentences read in the previous method.

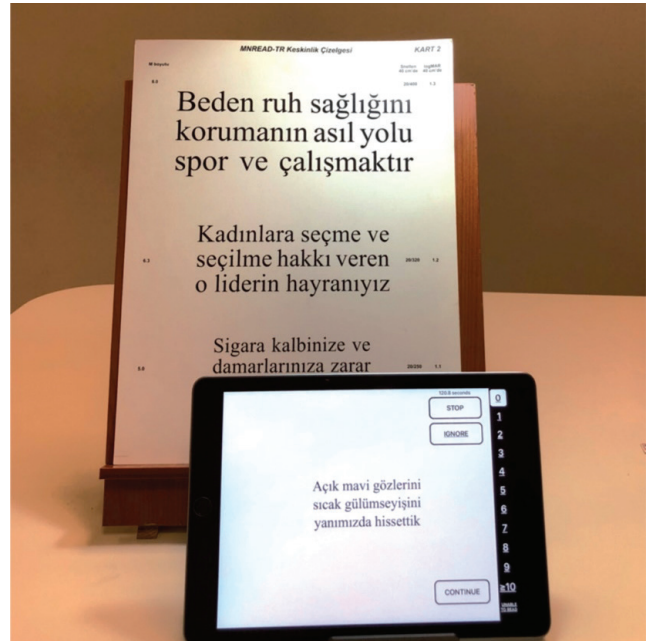
During the test with the printed MNREAD chart, an additional light source was directed at the paper (using a 200 cd/m<sup>2</sup> table lamp) in addition to the ceiling light.<sup>18</sup> The room lighting was 300 lux, while the MNREAD iPad application was set to a brightness of 200 cd/m<sup>2</sup>. Sentences were displayed once in both methods and the participants were asked to read the sentences out loud as quickly and accurate as possible until they reached a print size at which no words could be read. The practitioner measured the reading time with a stopwatch and recorded the number of incorrect/missing words for each sentence of the printed MNREAD chart test. MNREAD parameter calculation was performed by the same examiner (D.A.).

The tablet application method was implemented using the MNREAD iPad App (©2017) on an iPad with Retina display (MP2F2TU/A, 32 GB, 9.7 inches, 5<sup>th</sup> generation, 264 pixels/inch or 104 pixels/cm resolution, LED, backlit) held horizontally. The overhead light was kept on, with no additional lighting and the iPad set to 200 cd/m<sup>2</sup>. This light level was not strong enough to disturb low-vision patients with albinism and cone dystrophy. None of the participants with these diagnoses stated that they were uncomfortable with the light level or needed to reduce the light to see better. Incorrect/missing words were recorded by the practitioner and the graphs of the parameters were generated automatically by the application. The reading speed curve for normally sighted individuals is similar in general (Figure 2). However, that standard curve cannot be drawn when measuring reading speed in individuals with low vision (Figure 3).<sup>9</sup>

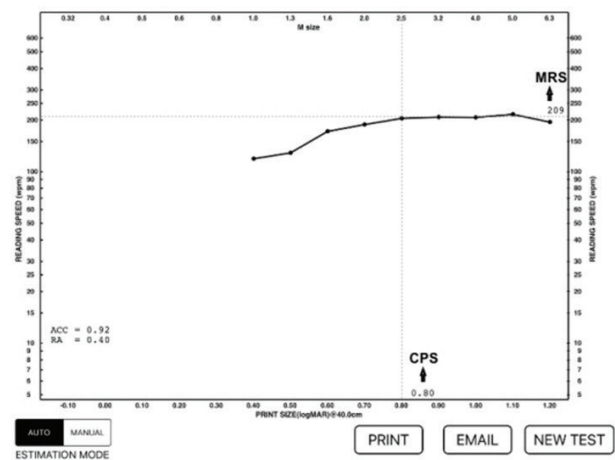
In this experimental study, the paired samples t-test/Wilcoxon signed-rank test was used to compare the two testing methods. Bland-Altman plots were used for comparative analysis of MNREAD chart/application performance. IBM SPSS Statistics Version 20.0 (IBM Corp, Armonk, NY, USA) statistical software package was used for all statistical analyses. Statistical significance was accepted as p<0.05 for all tests.

## Results

The normally sighted group consisted of 92 people (37 males and 55 females) with a mean age of 26.24±5.97 years (median, 25). The low-vision group consisted of 24 people (12 males and 12 females) with a mean age of 50.92±29.45 years (median, 57). Of the low-vision individuals, 13 (54%) had age-related macular degeneration (AMD), 7 (29%) had albinism, and 4 (17%) had cone dystrophy. The mean distance visual acuity in this group was 0.73±0.20 logMAR (0.21±0.09 decimal).



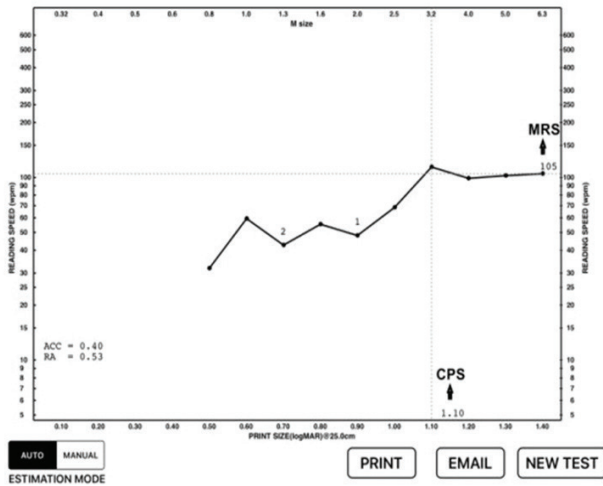
**Figure 1.** The printed and the tablet application forms of the Turkish version of the Minnesota Low Vision Reading (MNREAD) charts (with the permission of Aysun İdil)



**Figure 2.** An example of the MNREAD curve of a normally sighted participant with RA = 0.40 logMAR CPS = 0.80 logMAR, ACC = 0.92, and MRS = 209 wpm. Reading speed shows a plateau  
RA: Reading acuity, CPS: Critical print size, ACC: Reading accessibility index, MRS: Maximum reading speed

The reading parameter values of individuals with normal vision obtained by printed chart and tablet application are shown in Table 1. No statistically significant difference was found in RA and CPS between the methods ( $p=0.083$  and  $p=0.075$ , respectively). However, MRS and ACC differed significantly between the methods ( $p<0.001$  for both) (Table 1). The mean MRS was significantly faster in the chart method (2.36 logWPM, 95% confidence interval [CI]: 2.35-2.38) than in the tablet application method (2.22 logWPM, 95% CI: 2.21-2.24) (Figure 4). The mean ACC was significantly higher with the chart (1.19, 95% CI: 1.16-1.23) than the application (0.86, 95% CI: 0.83-0.88) in normally sighted individuals ( $p<0.001$  for both).

The reading parameter values obtained with the two methods in individuals with low vision are shown in Table 2. There was no statistically significant difference in RA and ACC between the methods ( $p=0.159$  and  $p=0.103$ , respectively), while MRS and CPS differed significantly ( $p<0.001$  and  $p=0.015$ , respectively) (Table 2). The mean MRS was significantly faster with the printed chart method (1.89 logWPM, 95% CI: 1.78-2.01) than with the tablet application (1.77 logWPM, 95% CI: 1.68-1.87)

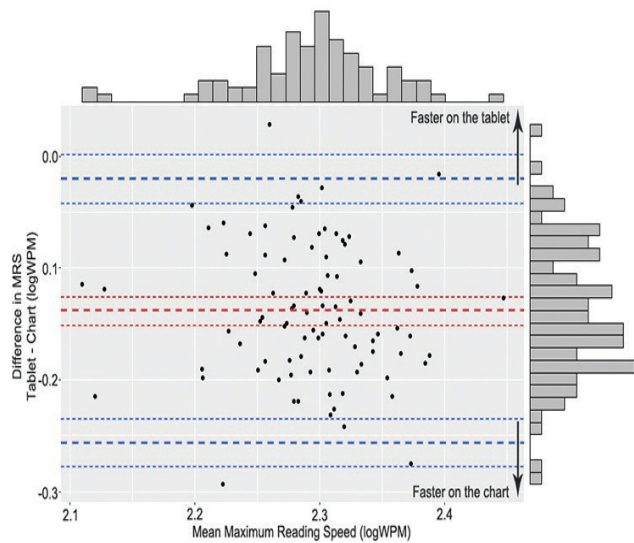


**Figure 3.** An example of the MNREAD curve of a low vision participant with RA = 0.53 logMAR, CPS = 1.10 logMAR, ACC = 0.40, and MRS = 105 wpm. Reading speed does not plateau  
RA: Reading acuity, CPS: Critical print size, ACC: Reading accessibility index, MRS: Maximum reading speed

(Figure 5). The mean CPS was found to be statistically higher with the chart (1.19, 95% CI: 1.16-1.23) than the application (0.86, 95% CI: 0.83-0.88) in low-vision individuals ( $p<0.001$  for both).

### Discussion

Assessment of reading performance in low-vision rehabilitation is important for determining reading aids and rehabilitation strategies and monitoring the rehabilitation process.<sup>19</sup> Calabrese et al.<sup>14</sup> compared the results obtained from the printed MNREAD chart and tablet application and found them to be consistent. Our study is a similar study using the Turkish version of MNREAD. In this study, RA results were similar with both methods in individuals with normal vision and low vision. RA and ACC results, which are important for near visual rehabilitation, were similar in individuals with low vision. This suggests that the MNREAD tablet application may be especially useful in the low-vision rehabilitation setting. The MNREAD



**Figure 4.** Comparison of the maximum reading speed (MRS) in the MNREAD tablet application and printed forms in the normally sighted group. Bland-Altman plots show the difference between measured MRS plotted against the mean MRS in normally sighted individuals. The red dashed lines show the average difference and the blue dashed lines show the limits of agreement ( $\pm 1.96$  SD). The dotted lines represent the 95% confidence interval

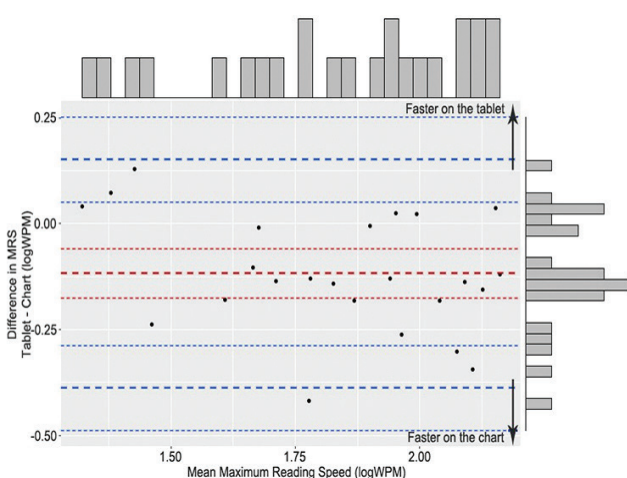
	MRS (WPM)	MRS (logWPM)	ACC	RA (logMAR)	CPS (logMAR)
Printed form	233.1±34.7	2.36±0.07	1.19±0.17	-0.04±0.10	0.06±0.10
Tablet form	169.3±23.4	2.22±0.06	0.86±0.11	-0.01±0.20	0.11±0.30
p-value	<0.001	<0.001	<0.001	0.083	0.075

WPM: Words per minute, MRS: Maximum reading speed, ACC: Reading accessibility index, RA: Reading acuity, CPS: Critical print size

**Table 2. Comparison of MNREAD parameters in the printed and the tablet application form of MNREAD in the low-vision group**

	MRS (WPM)	MRS (logWPM)	ACC	RA (logMAR)	CPS (logMAR)
Printed form	93.2±50.2	1.89±0.29	0.39±0.29	0.77±0.27	0.88±0.21
Tablet form	68.2±34.7	1.77±0.24	0.33±0.16	0.70±0.27	0.71±0.31
p-value	<0.001	<0.001	0.103	0.159	0.015

WPM: Words per minute, MRS: Maximum reading speed, ACC: Reading accessibility index, RA: Reading acuity, CPS: Critical print size



**Figure 5.** Comparison of the maximum reading speed (MRS) in the low vision group in the printed and the tablet application forms of MNREAD. Bland-Altman plots show the difference between measured MRS plotted against the mean MRS in low-vision individuals. The red dashed lines show the average difference and the blue dashed lines show the limits of agreement ( $\pm 1.96$  SD). The dotted lines represent the 95% confidence interval

iPad application has advantages such as being practical and fast, offering two polarities and different language options, recording reading speed, displaying graphical results, estimating the MNREAD curve, providing MNREAD parameter calculations, and saving and sharing the data.<sup>20</sup> These advantages increase the possibility of using the MNREAD application.<sup>14</sup>

There are limited studies in the literature regarding the use of tablets in near vision examinations. Varadaraj et al.<sup>21</sup> compared the results of tablet-based tests and MNREAD acuity chart test in near visual acuity test and found that the RA values were consistent. Although the results of their study are valuable, parameters other than RA were not considered. Calabrèse et al.<sup>14</sup> evaluated all parameters of the MNREAD reading test. Reading speed is generally considered the primary parameter in the studies investigating reading performance.<sup>22,23</sup> Calabrèse et al.<sup>14</sup> found higher MRS values with the printed charts than with the tablet application in the normally sighted group, and the difference was greater in those with high MRS. They attributed the difference in MRS values between printed and application methods to the difference in timing methods and suggested that a coefficient could be used to make the MRS

results equivalent in two forms.<sup>14</sup> In their study, they determined this equivalence coefficient to be 1.1 for MRS results in the normally sighted group. In our study, we found that the MRS values were also higher with the printed chart compared to the application in both the normal-sighted and low-vision groups, with an equivalence coefficient of 1.37 in both groups. It was seen that this coefficient can also be used for ACC in the group with normal vision.

In the study by Calabrèse et al.,<sup>14</sup> there was no significant difference between RA estimated with the printed chart and with the application in the normally sighted group. In our study, the RA values were similar with both methods in both groups. Xiong et al.<sup>24</sup> reported that RA is a more important criterion for reading performance than measuring near visual acuity. Therefore, finding similar RA with both methods is important in terms of reading performance evaluation in near vision examination.

Calabrèse et al.<sup>14</sup> reported that CPS, MRS, and ACC values were similar but RA values were better with the tablet application in the low-vision group. In our study, we found that RA and ACC values were similar in the low-vision group. Contrary to previous results, in our study, CPS in the low-vision group was smaller in the tablet application method. We believe displaying the sentences one after the other may have prevented confusion.

The differences between studies may be associated with the fact that we used the Turkish version of MNREAD. Differences in reading speeds in various languages have been demonstrated using the International Reading Speed Test (IReST). In this study, the reading speed for the 18-35 age group was determined as 166 wpm for Turkish and 228 wpm for English.<sup>25</sup> The difference between the results may also be related to the different age ranges in the studies. In a study investigating the effect of age, education, and gender on reading speed, the average number of syllables read by participants aged 20-35 was found to be higher than the average number of syllables read by participants aged 46-55.<sup>26</sup> The age ranges in our study were 18-49 years in normally sighted individuals and 18-89 years in low-vision individuals, while those in the study by Calabrèse et al.<sup>14</sup> were 8-72 years in normal-sighted individuals and 22-93 years in low-vision individuals. Although the groups in our study differed in age, there was no between-group comparison. Each group was tested by two methods separately and the results obtained from the methods were compared.

It was reported that ACC is an important indicator of reading performance in daily life in people with low vision.<sup>15,16,17</sup> In our study, the similarity of ACC results with both methods among low-vision participants was particularly promising for the use of MNREAD tablet application in this group. Consistency in important parameters of reading performance (RA and ACC) between the tablet-based and chart-based forms of the MNREAD-TR version in individuals with low vision is critical in terms of increasing the use of MNREAD iPad application.

The main difference between the iPad application and the printed chart was reported to be related to the digital image of the text. However, through the design of the iPad application on the Retina display, reading speed was suggested to be largely equivalent to the printed chart. The disadvantage of a reduced range of print sizes in the application form has also been overcome by increasing the viewing distance.<sup>14</sup>

Measurement of visual performance is necessary at various stages, such as evaluating the patient's functional vision, disease progression, and evaluating the success of treatment or rehabilitation. We would like to emphasize the importance of using continuous text-based methods in measuring a person's visual performance. With its many advantages, the MNREAD tablet application also seems to be a good option for clinical practice.

#### Study Limitations

Some of the limitations of our study include the heterogenic distribution of diagnoses of low-vision patients, the small number of patients in the low-vision group, and the dissimilarity of patients in the low-vision group and the normal-vision group in terms of age and gender. However, we do not consider these limitations critical as the groups in the study were not compared to each other, but each group was evaluated within itself in terms of MNREAD parameters.

#### Conclusion

Our study contributes to the literature by expanding the evaluation of the MNREAD tablet application in a language other than English. According to our results, the MNREAD tablet application can be preferred especially in the low-vision group for RA and ACC results, which are the most important determinants of reading performance. The reading speed difference and coefficient of equivalence between the two methods should be investigated in further studies. Similar studies need to be planned for different languages, with more participants in specific groups with the same diagnosis and similar age range and visual acuity.

#### Ethics

**Ethics Committee Approval:** Ankara University Faculty of Medicine Clinical Research Ethics Committee /24.09.2018/ decision no: 15-1023-18.

**Informed Consent:** Obtained.

**Peer-review:** Externally peer reviewed.

#### Authorship Contributions

**Surgical and Medical Practices:** D.A., E.Ş., A.İ., Concept: D.A., E.Ş., A.İ.,

**Design:** D.A., **Data Collection or Processing:** D.A., E.Ş., **Analysis or Interpretation:** D.A., E.Ş., A.İ., **Literature Search:** D.A., E.Ş., **Writing:** D.A., E.Ş.

**Conflict of Interest:** No conflict of interest was declared by the authors.

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