Low Vision

Standardized Assessment of Reading Performance: The New International Reading Speed Texts IReST

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Purpose. There is a need for standardized texts to assess reading performance, for multiple equivalent texts for repeated measurements, and for texts equated across languages for multi-language studies. Paragraphs are preferable to single sentences for accurate speed measurement. We developed such texts previously in 6 languages. The aim of our current study was to develop texts in more languages for a wide range of countries and users, and to assess the reading speeds of normally-sighted readers.

Methods. Ten texts were designed for 17 languages each by a linguist who matched content, length, difficulty, and linguistic complexity. The texts then were used to assess reading speeds of 436 normally-sighted native speakers (age 18–35 years, 25 per language, 36 in Japanese), presented at a distance of 40 cm and size 1 M, that is 10-point Times New Roman font. Reading time (aloud) was measured by stopwatch.

Results. For all 17 languages, average mean reading speed was 1.42 ± 0.13 texts/min (±SD), 184 ± 29 words/min, 370 ± 80 syllables/min, and 863 ± 234 characters/min. For 14 languages, mean reading time was 68 ms/character (95% confidence interval [CI] 65–71 ms). Our analysis focussed on words per minute. The variability of reading speed within subjects accounts only for an average of 11.5%, between subjects for 88.5%.

Conclusions. The low within-subject variability shows the equivalence of the texts. The IReST (second edition) can now be provided in 17 languages allowing standardized assessment of reading speed, as well as comparability of results before and after interventions, and is a useful tool for multi-language studies (for further information see www.amd-read.net). (*Invest Ophthalmol Vis Sci.* 2012;53:5452–5461) DOI: 10.1167/iovs.11-8284

For most people reading is a key function in everyday life. Standardized assessment of reading performance is necessary to perform repeated measurements based on equivalent texts within one language. Furthermore, standardized texts are a prerequisite for multi-language reading studies. Assessment of reading performance is important in reading disorders, such as low vision, neurologic reading disorders, and developmental dyslexia, but also after multifocal intraocular lens implantation.

Well developed texts with single sentences for measuring reading acuity, reading speed, and critical print size are available, such as MN Read or Radner's charts.[1–5] However, for measuring reading speed, a whole paragraph of text is preferable to single sentences, because the percentage error of reading time measurements in seconds is smaller for longer texts. Furthermore, reading whole paragraphs is closer to the demands of everyday reading.

To our knowledge, no comparable texts currently are available (except for young children) that have been standardized according to linguistic criteria. We developed such texts previously in 6 different languages,[6,7] that is the International Reading Speed Texts (IReST), first edition. The IReST are not in competition with existing reading tests. Rather, they are a supplemental tool that closes a gap in reading diagnostics.

The purpose of our current study was to develop texts in a wide range of additional languages to allow international multi-language studies in the future, and to provide benchmarks for reading speeds in normally-sighted readers.

Methods

Development of the Texts: The Linguistic Work

Ten paragraphs of German text were designed by a linguist from material for sixth grade reading (age 10–12 years) with a mean length of 132 words (SD ± 3.2). They were matched for difficulty and linguistic/syntactic complexity according to the theory of Gibson.[8,9]

The paragraphs of texts (in the following named "texts") were translated into 16 languages (Arabic, Chinese, English, Finnish, French, Hebrew, Italian, Japanese, Dutch, Polish, Portuguese/Brazilian, Swedish, Slovenian, Spanish, Russian, and Turkish), and adapted by linguists, all native speakers of the respective language, to be similar in difficulty and linguistic complexity to the German original. Additionally, the original demand was to make them similar in word and character counts. The number of words for all 10 Swedish texts (146) and the number of characters for all 10 Chinese texts (153) were identical.

The Chinese language is logographic and monosyllabic. A Chinese character represents a morpheme with one syllable, and a Chinese word in our texts consists of 1 to 4 Chinese characters. Unlike alphabetic languages, there are no demarcations between Chinese words, for example a space, and consequently it often is difficult to identify a word. Traditionally, reading speed of Chinese text has been measured in number of characters per minute, which we believe is the best measure for Chinese speakers. However, for studies comparing different languages, measuring reading speed in words per minute is desirable. For this purpose, we developed a two-step approach to identify a Chinese word: In step 1, we identified all the words that were found in two major Chinese dictionaries[10,11] and meaningful in the context. In step 2, for those Chinese characters that were not included

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Table 1. Counts per Text

Language Code	Words	Syllables	Characters
Ara	119.2 (3.8)	292.7 (6.1)	528.2 (5.9)
Chi	95.0 (5.4)	153.0 (0.0)	153.0 (0.0)
Dut	141.4 (3.6)	231.3 (7.2)	685.7 (7.9)
Eng	153.5 (9.1)	210.7 (6.3)	664.5 (9.7)
Fin	101.5 (3.8)	268.1 (7.8)	678.1 (3.2)
Fre	133.5 (6.5)	205.8 (10.1)	681.4 (8.3)
Ger	132.2 (3.2)	226.5 (6.8)	678.5 (5.5)
Heb	121.6 (6.1)	300.2 (13.4)	541.6 (34.7)
Ita	134.8 (5.0)	291.6 (12.4)	683.3 (5.8)
Jap	159.5 (3.2)	369.7 (7.6)	295.5 (8.5)
Pol	126.8 (3.9)	270.4 (6.0)	699.5 (4.1)
Por	133.7 (7.1)	277.9 (6.4)	675.0 (12.6)
Rus	126.5 (7.7)	301.7 (23.7)	678.4 (48.3)
Slo	137.0 (7.8)	176.1 (4.2)	684.3 (8.1)
Spa	142.9 (6.6)	343.7 (4.1)	670.0 (7.6)
Swe	146.0 (0.0)	240.2 (4.6)	673.2 (1.7)
Tur	109.3 (1.8)	293.6 (6.1)	696.1 (14.9)

Means (SD) for the 10 texts per language.

in words identified in step 1, we used those characters to construct words based on grammatical rules[12,13] and meaning in the context.

A Chinese reader recognizes a character by its pattern, not by counting strokes. Thus, the number or spatial configuration of strokes does not affect reading speed. Therefore, we do not use the information about the number of strokes per character for calculating reading speeds, because these depend more on the frequency of the characters in the texts.

For the Arabic language, it was necessary to find a way of formulating the texts so that they would match the different Arabic speaking countries. We tested this in a group, where 25 students from eight different Arabic countries participated. There were no significant differences between their reading speeds.[14] For French (France/Canada) and Portuguese (Portugal/Brazil) we made sure that the texts also were familiar to speakers of the respective country, mainly by careful word selection and pilot testing with subjects who were not part of the main study. The Japanese texts were written in standard KanaKanji-Script, including Hiragana, Katakana, and Kanji. Table 1 shows the number of words, syllables, and characters per text.

During the analysis it became clear that the most important issue was the same content in the different languages—as the amount of information that must be processed. Thus, we accepted unavoidable differences in text length, especially if alphabetic and nonalphabetic languages are compared.

After developing the first version of the texts in each language, the linguists conducted a pilot study with five normal subjects. Texts were presented at a viewing distance of 40 cm and a size of 1 M, or 10-point Times New Roman font, for the 15 alphabetic languages; 1 M-unit subtends 5 minutes of arc at 1 m. It measures 1.454 mm or 1/7 cm or almost 1/16 inch.[15] These texts were not designed for determining reading acuity and, therefore, are provided only in 1 M letter size, which corresponds to many newspaper print sizes.[16] Texts were printed in black on white paper at high contrast (Michelson contrast 90% or higher). The paragraphs had a maximum line length of 8.5 to 10.0 cm. The mean number of lines/text was 14.3, for Chinese 8.5. Languages read from left to right were left justified and vice versa.

The texts were read aloud, and if there were parts where the readers hesitated or struggled, the texts were modified in the pilot study.

Procedure for Establishing Normal Reading Speeds

In the main study, the newly designed texts then were used to assess the reading speeds of 436 normally-sighted subjects who were native speakers of the respective languages (25 per language, 36 in Japanese). All texts were unknown to the readers. Participants were 18 to 35 years of age with normal or corrected-to-normal vision as determined by an ophthalmologic/optometric examination.

The texts were printed in the same format as described above for the pilot study and were read aloud at a distance of 40 cm. A stopwatch was used to measure reading time. Words read incorrectly or omitted were counted. However, such error counts were ignored for the following calculations because they were not documented completely in all languages and they occurred very rarely.

Figure 1 shows an example of a text with the basic statistics.

The research adhered to the tenets of the declaration of Helsinki.

Statistical Evaluation

For calculation of reading speed, in our previous reports we used characters (with spaces and punctuation marks) to measure reading speed because the texts were nearly identical with respect to this variable.[6,7] However, considering the different language characteristics of the 17 languages (e.g., in Hebrew and Arabic the vowels are not or only partly written, while Chinese and Japanese are nonalphabetic), in our current study we assessed all reading speeds in four different ways: texts/min, words/min, syllables/min, and characters (without spaces and punctuation marks)/min. Means and SDs were computed for each language using these four measures of reading speed.

To test for differences among the 10 texts for each language separately, we performed a mixed-effects model analysis of variance (ANOVA) of words per minute with the fixed factor "text" (10 levels) and the random factor "subject" (25 levels in 16 languages and 36 subjects in Japanese). The parameters were estimated using Restricted

In a small town a greengrocer had opened a shop that was located above a deep cellar. Every night, mice came in droves out of this cellar into the shop. They ate apples and pears, grapes and nuts and did not spare the vegetables and potatoes either. No goods that were in the shop were safe from the small intrusive rodents between midnight and sunrise. As long as there was noise in the streets at night and cars were driving by, the mice still stayed quietly in the cellar. But as soon as the old clock on the town hall had struck midnight and it became quiet in the street, they came out in droves, enjoyed the sweet fruits and celebrated real feasts, whose remains filled the owner with despair every morning when he entered the shop. So he tried to protect himself against the mice. At first he set up traps all over the shop.

number of text: 1
name of text: Mice
performance category: AB
number of words: 156
number of syllables: 205
number of characters: 662
reading time in seconds (mean ± SD): 40.4 ± 6.2
reading speed (mean ± SD) words/minute: 236 ± 29

Figure 1. Sample text in English together with the basic statistics.

Table 2. Reading Speeds per Minute Expressed in Four Units for Each of 17 Languages

Language Code	N	Texts/Min	Words/Min	Syllables/Min	Characters/Min
Ara	250	1.16 (0.17)	138 (20)	339 (48)	612 (88)
Chi	250	1.67 (0.19)	158 (19)	255 (29)	255 (29)
Dut	249	1.43 (0.21)	202 (29)	330 (49)	978 (143)
Eng	249	1.49 (0.18)	228 (30)	313 (38)	987 (118)
Fin	250	1.59 (0.18)	161 (18)	426 (49)	1078 (121)
Fre	249	1.46 (0.18)	195 (26)	301 (39)	998 (126)
Ger	249	1.36 (0.13)	179 (17)	307 (30)	920 (86)
Heb	250	1.54 (0.25)	187 (29)	462 (73)	833 (130)
Ita	249	1.39 (0.20)	188 (28)	405 (61)	950 (140)
Jap	360	1.21 (0.19)	193 (30)	447 (69)	357 (56)
Pol	249	1.31 (0.18)	166 (23)	354 (49)	916 (126)
Por	250	1.35 (0.22)	181 (29)	376 (60)	913 (145)
Rus	250	1.46 (0.27)	184 (32)	439 (78)	986 (175)
Slo	250	1.32 (0.21)	180 (30)	232 (38)	885 (145)
Spa	250	1.53 (0.19)	218 (28)	526 (64)	1025 (127)
Swe	250	1.36 (0.23)	199 (34)	327 (56)	917 (156)
Tur	250	1.51 (0.23)	166 (25)	444 (66)	1054 (156)

Means (±SD), 10 texts per language. The number of observations per language is given in the second column (5 outliers excluded). The total variability is summarized by the SD.

Maximum Likelihood (REML) with the statistical package JMP 9.01 (SAS, Cary, NC). We tested for normality of the residuals and found, after adjustment of the significance level according to Bonferroni-Holm, only 3 of 17 significant departures from this assumption. A departure from normality does not invalidate the ANOVA due to the large number of observations according to the central limit theorem.

Differences between the texts in each language were assessed by Tukey's HSD post hoc test for 765 comparisons (45 pair-wise comparisons for 17 languages).[17] We considered differences of >10 words/min as clinically relevant and present only these results. Of the total 4359 reading time values (10 texts in each language, 25 subjects in 16 languages, and 36 in Japanese, one missing value), five outliers were excluded from further calculations by the following criterion—if the absolute value of the residuals exceeded 4 SDs of the residuals, a value was declared an outlier.

For analysis of reading speeds dependent on the different units, we apply linear regression through the origin and display the 95% confidence limits of the regression lines together with the 95% confidence intervals (CIs) for the individual observations. For individual reading times we performed an ANOVA to estimate the variance components between and within subjects.

Results

The mean (±SD) number of words, syllables and characters for the different languages are shown in Table 1 (see above), and the mean reading speeds are shown in Table 2.

The average mean for all languages is 1.42 ± 0.13 texts/min (±SD), 184 ± 29 words/min, 370 ± 80 syllables/min, and 863 ± 234 characters/min. Reading speed in texts/min corresponded to a mean reading time of 43.7 ± 7.8 sec/text. For the nonalphabetic languages Japanese and Chinese, characters per minute show speeds that are similar to syllables per minute in the other languages. In Hebrew and Arabic, where vowels are not or only partially written, the reading speed in characters per minute is lower compared to other alphabetic languages.

Figure 2 shows the reading speeds in three different units (words/min, syllables/min, char/min), dependent on the number of words, syllables, or characters per text in the 17 languages. To prevent too many overlaps of data points, the 17 languages have been divided into two sets of 8 or 9 languages for each of the three units of speed. It becomes clear that the different languages are characterized differently depending on the unit used. Positive correlations are expected because the counts of words, syllables, and characters appear simultaneously in the abscissa and the ordinate. However, because there are only 10 texts per language these correlations are not expected to be significant.

Figures 2a–2f display a linear regression through the origin together with the 95% CI of the fit and the 95% confidence region of the individual values. The slopes for all figures are identical, namely 1.415 texts/min (95% CI 1.407–1.422 texts/min), which corresponds to the overall average of the third column in Table 2. The 90% density ellipses are shown in all six plots for each language. Figures 2a and 2b show that the more words per text, the higher the number of words per minute because reading speed for all texts is approximately 1.4 texts/min, that is a reading time of 44 seconds/text.

Figure 3 displays the reading time in ms per syllable, which is proportional to the number of characters per syllable. The slope of this line specifies the mean reading time per character for all 17 languages. For 14 languages this is 68 ms (95% CI 65–71 ms).

The relative variability of reading speeds in words per minute within and between subjects for each language is shown in Table 3. The variability is caused mainly by differences between subjects (75%–93%), that is the differences between the readers of the 10 texts, whereas the texts account only for an average of 11.5% of the variability.

Figure 4 represents the raw data for Spanish for each subject and all texts. As pointed out in Table 3, the variability between subjects is much larger than within each subject (only 11.2% of the total variability for Spanish).

The comparison between the texts in each language showed 331 statistically significant differences out of 765 differences (45 pairwise comparisons for each of the 17 languages) after adjustment for multiple testing according to Tukey's HSD test. (Without adjustment the number of significant differences would have been 468.) This large number is explained by the fact that we performed the comparisons within one subject, and that the variability within one subject is much smaller than the variability between subjects. Only 81 of the 765 comparisons showed a difference between the criterion "statistically significant" and "difference

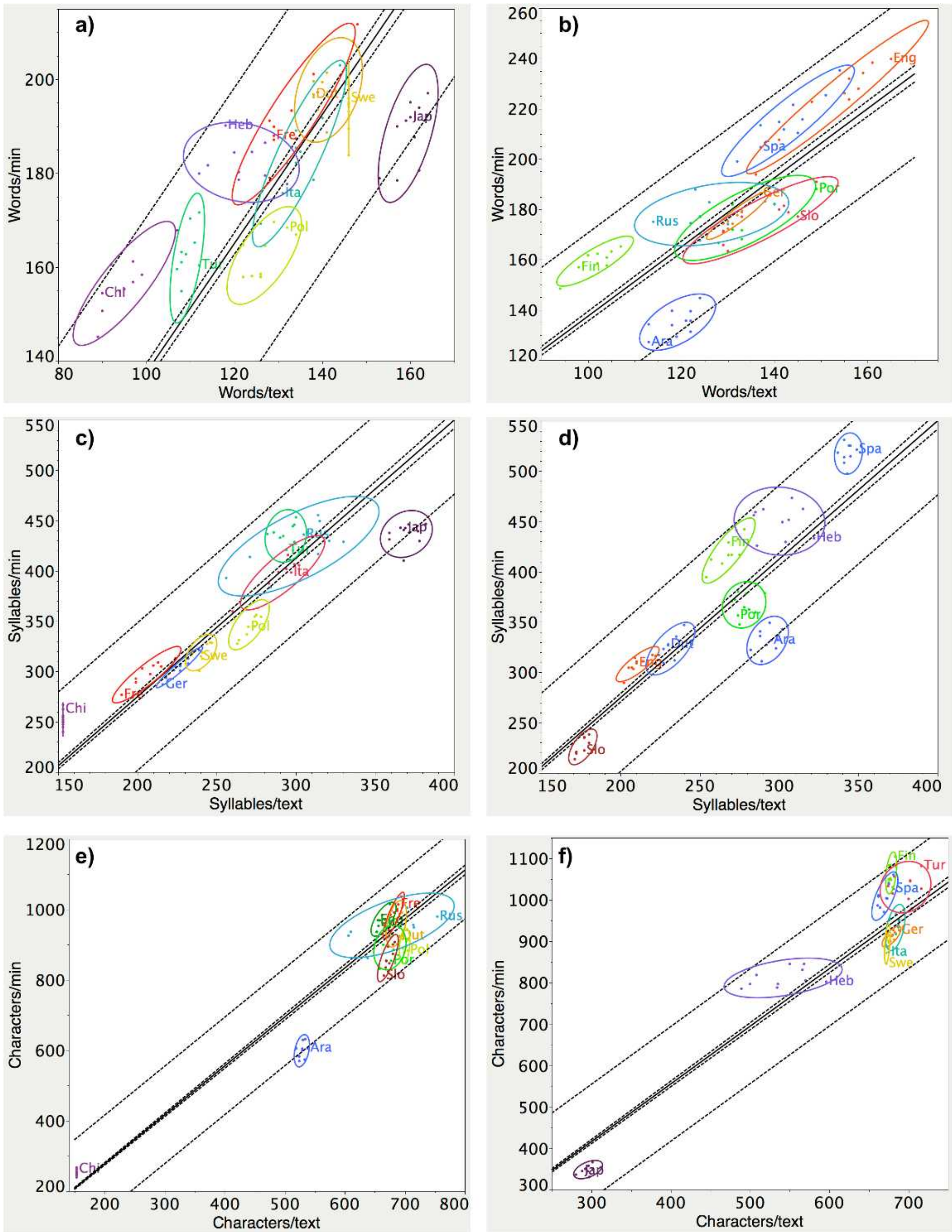

Figure 2. Detailed overview of the summary data from Tables 1 and 2 showing the individual 170 texts for the three units that express the length of a text: words (**a**, **b**), syllables (**c**, **d**), and characters (**e**, **f**). All six figures (**a**–**f**) show a linear regression through the origin together with the 95% CI of the estimated slope (*inner dashed curves*) and the 95% confidence region of the individual values (*outer dashed curves*). The slope for all three figures is identical, namely 1.415 texts/min (95% CI 1.407–1.422 texts/min), which corresponds to the overall average for the third column of Table 2. Since the reading time and reading speed per text are nearly identical for all 17 languages within the 95% CIs for the individual texts from 1.1 to 1.7 texts/min, there is a trivial linear relationship for the units per minute with the number of units per text. The 90% density ellipses in all three plots for each language are constructed such that they contain in the mean 9 of 10 texts. (**a**–**f**) The different languages are characterized differently depending on the unit used. Few significant correlations were expected because of only 10 texts per language. (**a**, **b**) Reading speed in words per minute dependent on the number of words per text. The more words per text, the higher the number of words per minute because the reading time for all texts is very similar (the number of words for all 10 Swedish texts was the same: 146). (**c**, **d**) Reading speed in syllables per minute dependent on the number of syllables per text. Here the Spanish texts are read with the highest number of syllables per minute because Spanish has many short syllables (Fig. 3). The opposite is true for Slovenian. (**e**, **f**) Reading speed in characters per minute dependent on the number of characters per text. Even if we include the nonalphabetic languages Chinese and Japanese, we obtain the same *regression line* through the origin with a slope of 1.4 texts/min. Arabic and Hebrew have the lowest number of characters/text among the alphabetic languages and correspondingly the lowest reading speed expressed in characters per min, because the vowels are not or only partly written. All the other languages are very close together in number of characters per text and characters per minute.

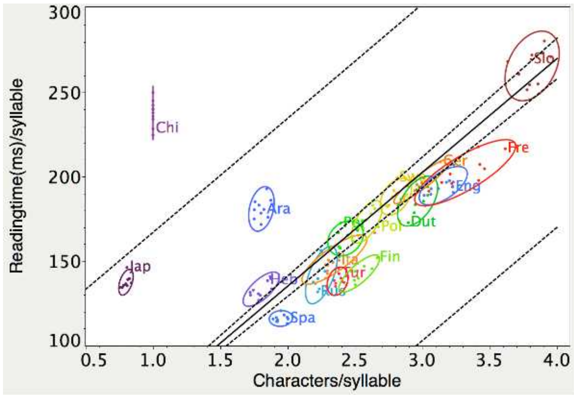

Figure 3. Reading time (ms) per syllable dependent on the number of characters per syllable. The reading time per syllable is proportional to the number of characters per syllable. The slope of this line corresponds to the mean reading time per character for all 17 languages, which turns out to be 68 ms per character (95% CI of the means 65–71 ms) for 14 languages (except Arabic, Chinese, and Japanese). The SD of the residuals is ±50 ms/syllable. In Japanese, one character can consist of more than one syllable and in Chinese, one character corresponds exactly to one syllable. Among the alphabetic languages, Arabic and Hebrew have the lowest number of characters per syllable because of the missing vowels. For the remaining alphabetic languages, Spanish has the lowest number of characters per syllable (1.95) and correspondingly the lowest reading time per syllable (116 ms). In Slovenian we observe the longest reading time per syllable (266 ms) together with the highest number of characters per syllable (3.8).

>10 words/min." In the following, only the clinically relevant differences (>10 words/min) are considered. The correlations of reading time among the 10 texts were high: mean pairwise "*r*" ranged from 0.772 in Chinese to 0.934 in Swedish. In Table A1 the reading speeds expressed as words per minute for each language are shown for each text. Texts with the same letter do not differ by more than 10 words/min.

In Table 4 we provide the lower normal 2.5% quantiles of reading speed (words per minute) taking into account that reading speed is influenced by age (here 18–35 years) and reading skill.

Discussion

Our study was performed to develop equivalent and standardized text passages in different languages, and to assess reading speeds of normally-sighted young adults during reading unknown texts. The IReST differs from prior text charts that used single sentences by employing linguistically standardized paragraphs. They close a gap in the diagnostics of reading performance. The paragraphs are designed to resemble everyday life situations of reading continuous text, such as in books or newspapers. The level of difficulty corresponds to sixth grade reading (10–12 years), which is comprehensible for teenagers and adults. Due to lower variance, measuring reading time of a complete paragraph rather than a single sentence or random words is more reliable. Furthermore, it can provide some information about fluency, fatigue, and mistakes.

Other reading tests are valuable for other indications: The MN Read[1–3] and Radner[4,5] texts use short and simple (second and third grade material) single sentences in different print sizes to assess reading acuity, critical print size, and magnification need.[18] Radner compared reading speeds of German-speaking readers of the single-sentence Radner texts (third grade sentences)[5] to those of paragraphs from the Zuercher Reading Test[19] (ZRT, standardized for fourth to sixth grade children) and found a high correlation between the short sentences and the ZRT, but a mean difference of 40 words/min—the single sentences being read much faster. This can be attributed at least partially to the higher linguistic difficulty of the ZRT, and no conclusion can be drawn in regard to the difference between one sentence and paragraph reading.

Table 3. Summary Statistics for the Comparison of Texts within a Language with Respect to the Reading Speed in Words per Minute

Language	Percentage of Total Variability due to the Subjects within a Language	Percentage of Total Variability due to the Different Texts within 1 Reader	SD (Words/Min) of Variability between Subjects	SD (Words/Min) of Variability within a Subject	F Ratio	*P* Value
Chi	75.5	24.5	15.5	8.8	13.2	<0.0001
Fin	81.7	18.3	16.4	7.7	9.5	<0.0001
Heb	85.3	14.7	27.1	11.2	3.3	0.0010
Ger	85.5	14.5	15.6	6.4	11.7	<0.0001
Ita	86.5	13.5	25.5	10.1	19.6	<0.0001
Ara	87.6	12.4	18.3	6.9	14.5	<0.0001
Pol	88.8	11.2	21.7	7.7	10.7	<0.0001
Spa	88.8	11.2	25.5	9.0	32.7	<0.0001
Eng	89.2	10.8	25.9	9.0	64.6	<0.0001
Por	89.8	10.2	27.3	9.2	19.8	<0.0001
Jap	90.0	10.0	28.4	9.5	21.1	<0.0001
Slo	91.1	8.9	28.2	8.8	22.6	<0.0001
Dut	91.9	8.1	28.8	8.5	6.9	<0.0001
Rus	92.0	8.0	31.1	9.2	10.4	<0.0001
Tur	92.3	7.7	23.6	6.8	23.5	<0.0001
Fre	92.7	7.3	23.6	6.6	49.0	<0.0001
Swe	92.9	7.1	32.9	9.1	7.2	<0.0001

Percentage of total variability of reading speeds (words per minute) for each language, which is due to the differences between the readers of the 10 texts ($n = 25$ for 16 languages, $n = 36$ for Japanese) and percentage of total variability due to the different texts within one subject. The next two columns provide the SDs in words per minute of the variability between and within the subjects. The last two columns provide the F ratios together with their *P* values for the hypothesis that all texts are equal. The numerator degrees of freedom is 9 for each language, and the denominator degrees of freedom is the number of observations per language minus the number of subjects for this language minus 9.

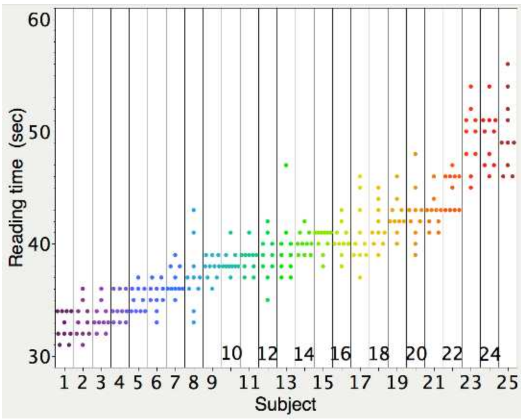

FIGURE 4. Individual reading times (sec) for the 25 Spanish subjects and the 10 texts. The total variability (SD ± 5.17 sec) mainly is due to the variability among the subjects (88.8%). The SD within one subject is only 1.76 seconds.

Random word reading tests can be helpful to find typical mistakes to get an idea about the location of a scotoma (Nair UK, et al. *IOVS* 2006:ARVO E-Abstract 3481). The Colenbrander Mixed Contrast Reading Cards[20] assess the influence of contrast sensitivity on reading of unrelated simple sentences at fourth grade level. The Pepper Test was reported to be useful in designing training programs in different low vision conditions.[21,22] Therefore, all these different text charts have their specific indication and supplement each other regarding specific aspects of reading, and cannot be compared directly.

Another new feature of IReST is the fact that they provide a set of 10 texts in each language for repeated measurements. Since equivalent sets of 10 texts are available in 17 languages, they provide a new tool for international multi-language studies. Due to the language characteristics, the counts of words, syllables, and characters differ considerably among the languages (Table 1). The text, as a unit of the same content in all languages, is processed in a quite comparable time between the languages. Therefore, in normal subjects, the differences in spatial length of the texts (number of lines) between languages do not seem to have a major role, because the perceptual span,[23] that is the number of letters perceived during one fixation, is sufficient in normal subjects. This span can be expected reasonably to be slightly different between different languages due to the varying average word length. Further analysis showed different reading speeds for the different units, which depends on the language structure (Fig. 2). In our previous reports, we used characters (with spaces and punctuation marks) to measure reading speed because the texts were nearly identical with respect to this variable.[6,7] For scientific use, especially from a speech articulation point of view, syllables per minute can be more conclusive, whereas words per minute are not suitable because of differences in word lengths between languages. However, for everyday life, words per minute is more common and more intuitive, and can be considered as a reasonable compromise, if all languages are considered. All these measures are displayed in the IReST charts to provide the user with the units needed for a specific question (Fig. 1).

Mean reading time per character for 14 languages (except Arabic, Chinese, Japanese) is 68 ms (95% CI 65–71 ms) determined by the slope of the line in Figure 3. This explains why Spanish is the fastest and Slovenian the slowest among the alphabetic languages (excluding Arabic and Hebrew) if reading speed is based on syllables per minute, because in Slovenian a syllable has approximately twice the number of characters.

TABLE 4. Normal Lower Reference Values for Reading Speeds (Words per Minute) for 17 Languages

Language	2.5% Quantile of Reading Speed (Words/Min)
Ara	96
Chi	127
Dut	149
Eng	161
Fin	126
Fre	154
Ger	142
Heb	127
Ita	144
Jap	148
Pol	108
Por	133
Rus	125
Slo	132
Spa	159
Swe	146
Tur	115

The texts account for only 11.5% of the total variability (Table 3), that is they are well designed with a high equivalence between each other in each language. The individual reading speed, which depends on reading habits and skills, is the main reason for the variability. It also becomes clear that within one individual reader the variability is relatively low with a high correlation coefficient when reading all 10 texts ($r = 0.772$–0.934).

Age also has a role for reading speed. In this study, age 18 to 35 years was an inclusion criterion. We showed in a previous study using IReST[6] (first edition) that older subjects (aged 60–85 years) read more slowly by a factor of approximately 20% (English and German readers).

Based on the results and considering the different language structures, the following instructions for use are recommended: For use within one language direct comparison is possible for texts without a clinically relevant reading speed difference of $\leq$10 words/min (Table A1). Dependent on the question, any unit can be used (see above and Fig. 2). Between languages, in clinical studies normally only the relative difference of reading speed is needed, for example before and after interventions. Therefore, a direct comparison of absolute reading speeds between languages normally is not necessary, but possible using a correction factor.

Fields of Applications

The IReST charts are suitable for a wide field of applications, for assessment of reading speed for:

- Diagnostics.
- Course monitoring.
- Effect documentation after interventions.
- Low vision patients.
- Effect of multifocal intraocular lens implantation.
- Neurological reading disorders (e.g., hemianopia, alexia).
- Developmental dyslexia.
- Studies with normal subjects.

Two patient groups will be discussed in more detail.

Low Vision Patients

The aim of low vision rehabilitation is reading ability of common print (1 M). Patients with central scotoma regain reading ability by the use of an eccentric retinal locus and magnifying visual aids to compensate for the lower resolution.[24–30] Therefore, low vision patients must read the IReST with their magnifying aids—a requirement of everyday reading situations. In patients, the mistakes are, of course, much more frequent than in normal subjects and must be taken into account by subtracting the omitted or incorrectly read words from the entire number of words of the text when calculating the reading speed (60 $\times$ number of correctly read words/reading time in seconds).

The reading speeds in English and German native-speaking patients with age-related macular degeneration (AMD) were assessed in two studies using the IReST (first edition), when patients read the texts with appropriate magnification. A total of 40 English AMD patients had a mean reading speed of 0.44 $\pm$ 0.39 log char/sec, that is 38 words/min, viewed at their critical print size.[31] In 530 German AMD patients, the mean reading speed was 20 $\pm$ 33 words/min before and 72 $\pm$ 35 words/min after adaptation of optimal magnifying visual aids.[32]

Developmental Dyslexia

In this diagnosis, not only the speed, but also the kind of errors is important. For example, when measuring reading performance in developmental dyslexia, standardized texts previously were available only for young children and not for higher grades or adults. In a recent study in German teenagers (mean age 18 $\pm$ 3.3 years) using IReST (first edition), we found a mean reading speed of 184 words/min,[33] which does not differ from the cohort examined here of German young adults (18–35 years) with 179 words/min, which confirms that reading aloud does not increase after the age of 15 to 18 years (due to speech rate ceiling).[34] Therefore, these texts also close a gap for testing teenagers and young adults, especially in patients with developmental dyslexia. In developmental dyslexia research, it is of special interest to compare reading performance in different languages, because reading strategies depend very much on the orthographic regularity of a language.[35–37] The texts can open a new opportunity to perform multi-language studies in the research on developmental dyslexia.

To summarize, the IReST provide a reproducible outcome measure that will facilitate cross-language comparisons, and are suitable for monitoring the impact of eye disease and success of interventions. The second edition of the IReST charts with 17 languages will be available in 2012. For further information, see www.amd-read.net.

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Appendix

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(see Table A1)

Table A1. Reading Speeds for Each Text in Each Language, Ranked in Order of Decreasing Speed. Texts with the Same Letter in Performance Category A to F Differ not More than 10 Words per Minute

Language	No. of Text	Rank Order	Reading Speed (Words/Min)*	Performance Category				
Ara	3	1	148	A				
Ara	9	2	143	A	B			
Ara	7	3	142	A	B			
Ara	8	4	139	A	B	C		
Ara	5	5	139	A	B	C		
Ara	6	6	137		B	C		
Ara	4	7	136		B	C		
Ara	2	8	134		B	C		
Ara	1	9	132			C		
Ara	10	10	131			C		
Chi	2	1	170	A				
Chi	8	2	163	A	B			
Chi	6	3	162	A	B	C		
Chi	10	4	161	A	B	C		
Chi	3	5	159		B	C		
Chi	1	6	157		B	C	D	
Chi	4	7	157		B	C	D	
Chi	5	8	156		B	C	D	
Chi	7	9	152			C	D	
Chi	9	10	147				D	
Dut	2	1	211	A				
Dut	6	2	205	A	B			
Dut	8	3	204	A	B			
Dut	9	4	204	A	B			
Dut	4	5	203	A	B			
Dut	10	6	201		B			
Dut	5	7	200		B			
Dut	7	8	199		B			
Dut	3	9	197		B			
Dut	1	10	195		B			
Eng	4	1	244	A				
Eng	2	2	243	A				
Eng	8	3	237	A	B			
Eng	1	4	236	A	B			
Eng	7	5	232		B	C		
Eng	5	6	229		B	C		
Eng	3	7	227		B	C		
Eng	9	8	226			C		
Eng	10	9	211				D	
Eng	6	10	197					E
Fin	7	1	167	A				
Fin	5	2	165	A				
Fin	6	3	164	A				
Fin	1	4	164	A				
Fin	4	5	163	A				
Fin	8	6	161	A				
Fin	3	7	161	A				
Fin	10	8	159	A	B			
Fin	2	9	159	A	B			
Fin	9	10	150		B			
Fre	7	1	215	A				
Fre	1	2	205	A	B			
Fre	2	3	199		B	C		
Fre	8	4	197		B	C		
Fre	4	5	194			C		
Fre	5	6	192			C		
Fre	3	7	190			C	D	
Fre	10	8	190			C	D	
Fre	9	9	190			C	D	
Fre	6	10	182				D	

Table A1. Continued

Language	No. of Text	Rank Order	Reading Speed (Words/Min)*	Performance Category			
Ger	2	1	188	A			
Ger	4	2	185	A	B		
Ger	5	3	181	A	B	C	
Ger	9	4	180	A	B	C	
Ger	1	5	180	A	B	C	
Ger	8	6	178		B	C	
Ger	6	7	176		B	C	
Ger	10	8	176		B	C	
Ger	3	9	175		B	C	
Ger	7	10	174			C	
Heb	2	1	195	A			
Heb	4	2	191	A	B		
Heb	9	3	190	A	B		
Heb	6	4	189	A	B		
Heb	8	5	186	A	B		
Heb	5	6	184		B		
Heb	7	7	184		B		
Heb	1	8	184		B		
Heb	3	9	184		B		
Heb	10	10	183		B		
Ita	2	1	206	A			
Ita	3	2	194		B		
Ita	7	3	193		B		
Ita	8	4	188		B	C	
Ita	5	5	188		B	C	
Ita	9	6	187		B	C	
Ita	4	7	185		B	C	
Ita	1	8	181			C	D
Ita	10	9	179			C	D
Ita	6	10	174				D
Jap	10	1	201	A			
Jap	4	2	200	A			
Jap	6	3	199	A	B		
Jap	5	4	197	A	B		
Jap	9	5	196	A	B		
Jap	8	6	196	A	B		
Jap	2	7	190		B	C	
Jap	3	8	185			C	
Jap	7	9	184			C	
Jap	1	10	181			C	
Pol	5	1	172	A			
Pol	8	2	172	A			
Pol	4	3	172	A			
Pol	7	4	169	A	B		
Pol	6	5	168	A	B		
Pol	10	6	163	A	B		
Pol	9	7	162		B		
Pol	3	8	161		B		
Pol	2	9	161		B		
Pol	1	10	161		B		
Por	7	1	192	A			
Por	8	2	192	A			
Por	2	3	187	A			
Por	4	4	186	A			
Por	9	5	182	A	B		
Por	3	6	176		B	C	
Por	5	7	175		B	C	
Por	6	8	174		B	C	
Por	1	9	173		B	C	
Por	10	10	170			C	

Table A1. Continued

Language	No. of Text	Rank Order	Reading Speed (Words/Min)*	1	2	3	4	5	6
Rus	8	1	195	A					
Rus	4	2	190	A	B				
Rus	9	3	189	A	B	C			
Rus	3	4	186	A	B	C			
Rus	2	5	183		B	C	D		
Rus	7	6	183		B	C	D		
Rus	6	7	182		B	C	D		
Rus	5	8	180			C	D		
Rus	10	9	179			C	D		
Rus	1	10	175				D		
Slo	4	1	197	A					
Slo	7	2	186		B				
Slo	2	3	184		B	C			
Slo	8	4	184		B	C			
Slo	1	5	182		B	C			
Slo	6	6	181		B	C			
Slo	5	7	176			C	D		
Slo	9	8	176			C	D		
Slo	3	9	170				D		
Slo	10	10	168				D		
Spa	4	1	239	A					
Spa	2	2	229	A	B				
Spa	5	3	225		B	C			
Spa	1	4	219		B	C	D		
Spa	3	5	218			C	D	E	
Spa	9	6	216			C	D	E	
Spa	8	7	216			C	D	E	
Spa	7	8	214				D	E	
Spa	10	9	208					E	F
Spa	6	10	202						F
Swe	2	1	205	A					
Swe	5	2	204	A	B				
Swe	8	3	203	A	B				
Swe	1	4	201	A	B				
Swe	9	5	199	A	B				
Swe	6	6	199	A	B				
Swe	7	7	199	A	B				
Swe	10	8	197	A	B	C			
Swe	4	9	195		B	C			
Swe	3	10	188			C			
Tur	9	1	175	A					
Tur	3	2	175	A					
Tur	5	3	169	A	B				
Tur	6	4	167	A	B	C			
Tur	2	5	166	A	B	C			
Tur	4	6	164		B	C			
Tur	7	7	164		B	C			
Tur	8	8	163		B	C	D		
Tur	10	9	158			C	D		
Tur	1	10	153				D		

* Reading speed (words/min) is mean reading speed.