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The validity and reliability of short German sentences for measuring reading speed

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Abstract *Purpose:* To investigate whether short German sentences that have been developed to be highly comparable in number and length of words, as well as in difficulty and construction, are reliable and valid test items for measuring reading speed in order to use them for measuring simultaneously reading acuity and speed with the "Radner Reading Charts". *Methods:* Tests were performed in 198 persons: 99 university students (average age 23.6±2.8 years) and blue-collar apprentices (average age 18.4±2.5 years). Reading speed and the number of errors were determined first with 24 sentences for our recently developed German reading charts (14 words equal in difficulty, length and construction) and secondly with long paragraphs of the "Zuercher Reading Test" (ZRT; paragraphs 3–5, 261 words). *Results:* The overall mean reading speed obtained with short sentences was 209.6±41.0 words per minute (wpm), compared with 169.2±35.0 wpm for the ZRT ($P<0.001$). The correlation between the short sentences and the ZRT was high ($r=0.9$). Students read faster and made fewer errors than did the apprentices. Reliability analyses yielded an overall Cronbach's alpha coefficient of 0.98. The coefficient of selectivity of the 24 sentences (test items) varied from 0.75 to 0.88. *Conclusion:* The present study indicates that the 24 short single sentences we have tested are highly comparable in terms of both lexical difficulty and reading length, and it has demonstrated the validity and reliability of such sentences as test items for determining reading speed.

Introduction

In our modern, information-based society, the ability to read is essential for everyday life. Losing the ability to read severely reduces the independence of individuals and thus has a severe impact on quality of life. Although rehabilitative and surgical interventions can be performed to limit or reverse visual impairments, the health care providers tend to measure the necessity of treatments or rehabilitation by means of patient-based assessments and quality of life outcomes. It is therefore becoming increasingly necessary to use methods that reproducibly measure the impact of visual disabilities on the patient's everyday life and to show that the recommended therapies do indeed increase the patient's quality of life [7, 15, 16, 21, 23, 24]. Reading performance analysis may serve as a useful tool in such situations because the evaluation of reading speed and reading acuity is easy to perform and provides a large amount of information that can easily be interpreted.

The Salisbury Eye Evaluation Project has studied the visual abilities in an elderly population [7, 21, 24]. One of the project's studies has demonstrated that visual function decreases with age in terms of acuity, contrast sensitivity, glare and visual field [21]. Another of these studies has provided a more detailed insight into reading problems of elderly individuals [7], showing that 10.8% of 2,107 people reporting minimal difficulty in reading a

newspaper had a reading speed below 80 words per minute [21, 25], which is the lower limit for a recreational, sense-capturing reading performance. In addition, most of the patients suffering from vision problems have a strong desire to retain their reading ability or to get it back [4, 8, 10, 17, 18, 21, 23]. Thus, it seems to be evident that the evaluation of reading speed and reading acuity, or even better, of reading speed based on reading acuity, has clinical importance as a pre- or postoperative measure and for visual rehabilitation.

For clinical as well as research examinations, reading performance analyses have to be easy to perform, quick to administer and should provide reliable and valid results. Legge et al. have shown that it is possible to reliably examine reading speed with short sentences. To our opinion their MNREAD tests have created a clinically relevant basis for testing reading speed [2, 9, 13]. Bailey and Lovie indicated that it is possible to determine reading speed and reading acuity with short phrases in one simultaneous examination [3], a method that has also been applied to MNREAD acuity charts. [13] When reading speed is determined on the basis of reading acuity it is necessary to use highly comparable sentences (test items) in order to minimise variations in reading speed due to differences in the test sentences. We did this by developing sentences (test-items) that are highly comparable in terms of lexical difficulty, syntactical complexity, word length and position of words, and then standardising these sentences statistically on a group of volunteers [3, 19].

In the present study we have investigated whether short single sentences, which have been developed to be highly comparable in number and length of words as well as in difficulty and construction, are reliable and valid test items for reading speed analyses in order to subsequently use them for the simultaneous determination of reading acuity and reading speed.

Materials and methods

The study population consisted of (a) 99 university students (average age 23.6±2.8 years) and (b) 99 manually working blue-collar apprentices (average age 18.4±2.5 years). The students estimated that their average daily reading time was between 5 and 7 h, whereas the manually working apprentices thought to read between 0.5 to 2 h a day. All participants were consented to participate in the study. Visual acuity was at least 20/20 in each eye, and none of the participants suffered from diseases or received medication that could influence the results of the study. Tests were performed binocularly. All study procedures adhere to the Declaration of Helsinki for research involving human subjects.

The volunteers were asked to read the 24 sentences (Fig. 1), which have previously been selected for the "Radner Reading Charts" (RR chart) [19]. Since changes in reading speed should be mainly attributable to the print size and not to lexical difficulty, we decided to use 3rd-grade relative clauses, which represent the first complex but still easy readable adult sentences. These 24 sentences have been developed to be highly comparable in terms of grammatical difficulty as well as number (n=14), length and position of words and, thus, were created following rules that have previously been published in detail [19]. In brief: (1)The sentences incorporated relative clauses and had 3 lines and 14 words. (2) Each line had 27–29 characters including spaces (82–84 characters per sentence). (3) The first and second line each had 5 words. (4) The third line had 4 words. (5) The first word of the first and of the second line was a word of 1 syllable and 3 letters. (6) The second word of the second line was a word of 3 syllables and 10 letters. (7) This word was followed by a relative clause that (8) began with 3 short words, each of 1 syllable. (9) In the first line there was one noun of 2 syllables and another word (not a noun) of 2 syllables. (10) The third line began with a word of 2 syllables, followed by (11) a noun of 2 syllables. (12) The next word was the verb of the sentence, which was composed of 3 syllables. (13) The last word was a part of the verb and had 2 syllables.

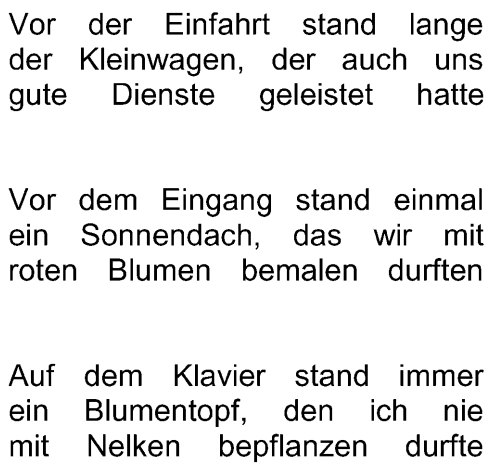


Fig. 1 Sample sentences (s1, s5, s18) from the 24 sentences used for the present study

Eight sentences were printed on each page. The type size was 12 point (font: Arial), and the reading distance was 40 cm. The luminance was 80–90 cd/m^2. Pages were presented on a reading stand, and the reading distance was determined with a 40-cm ruler and constantly verified during the procedure. The sentences were covered with a piece of paper, and the volunteers were asked to uncover sentence after sentence, reading each one aloud as quickly and accurately as possible. Volunteers were instructed to read the sentences to the end before correcting any reading errors. Reading time was measured with a stopwatch. Measurements were performed only by two experienced testers who had been trained in this standardised method prior to the study.

To provide the highest accuracy possible, the stopwatch method was performed as follows: The vocal onset could be anticipated with acceptable accuracy by looking for the initial pre-movements of the volunteer's lips when reading was initiated. The end of the sentence was easy to determine accurately. Reading speed in words per minute (wpm) was calculated on the basis of the number of words in a sentence (14 words) and the time needed to read the sentence (14 words × 60 s divided by the reading time). Reading errors were noted by marking the wrong word in the sentence on the study form. Errors were counted even when immediately corrected. To confirm the reliability of our stopwatch measurements, the reading performance of all volunteers was recorded on digital audio tape (DAT) and then re-analysed with a newly developed computer system [20].

To assess the validity of the reading speed results obtained with these short sentences, we also measured reading speed and reading errors using stopwatch measurements under the same con-

ditions for the long paragraphs 3, 4 and 5 of the " Zuercher Reading Test" (ZRT; a total of 261 words) [11]. The ZRT is a commercially available German-language reading test that has been standardised on four age groups of children (100 per group) as a test for dyslexia. The paragraphs increase in lexical difficulty from paragraph 1 to 5. The paragraphs 3, 4 and 5 are the ones that were standardised for 4th to 6th grade children.

Statistical analyses

Statistical analyses were performed using SPSS for Windows, Version 6.1. Group differences between students and apprentices as well as differences within the ZRT charts with respect to the reading speed and number of errors were analysed for significance by means of *t*-tests.

The data showed a fairly symmetric immodial distribution so that the assumption of a normal distribution for the mean, as required for the t-test was justified.

Correlation analyses were performed using Pearson correlation. Reliability was determined by calculating the Cronbach's alpha and the coefficient of selectivity of the 24 sentences (items). The cut-off level for statistical significance was set at $P<0.001$, two-tailed.

Results

Table 1 shows the results of reading speed analyses obtained for the 24 short sentences and for the long paragraph of the ZRT. Measurements with the 24 sentences revealed an overall mean reading speed of 209.6±41.0 wpm for all 198 readers (Table 1; Fig. 2). The students read significantly faster than the apprentices (students: 230.6±28.3 wpm; apprentices: 190.1± 41.9 wpm; $P<0.001$; Table 1; Figs. 2, 3). The mean reading speeds calculated for the 24 sentences varied between 202.5 and 215.2 wpm (mean 209.6±4.2 wpm; Fig. 2). To confirm the reliability of our stopwatch measurements, the reading performance of all volunteers was recorded on DAT recorded and then re-analysed with a newly developed computer system [19]. We found a high (r=0.939) correlation between the stopwatch measurements and the computer re-measurements. The distribution of reading errors between the various texts is given in Table 2. Because of their much greater reading practice, students made fewer reading errors (students: 0.08±0.31 errors per sentence; apprentices: 0.35±0.6 errors per sentence; both: 0.21±0.55 errors per sentence, students vs. apprentices: $P<0.001$; (Table 2, Fig. 4). Students read 177 (8%) of 2376 sentences incorrectly and the apprentices read 598 (25%) incorrectly. In most cases just one error was made (students: 83% of the incorrect sentences, apprentices: 73%; Fig. 4). The highest number of errors was 5 (one sentence per group; Fig. 4).

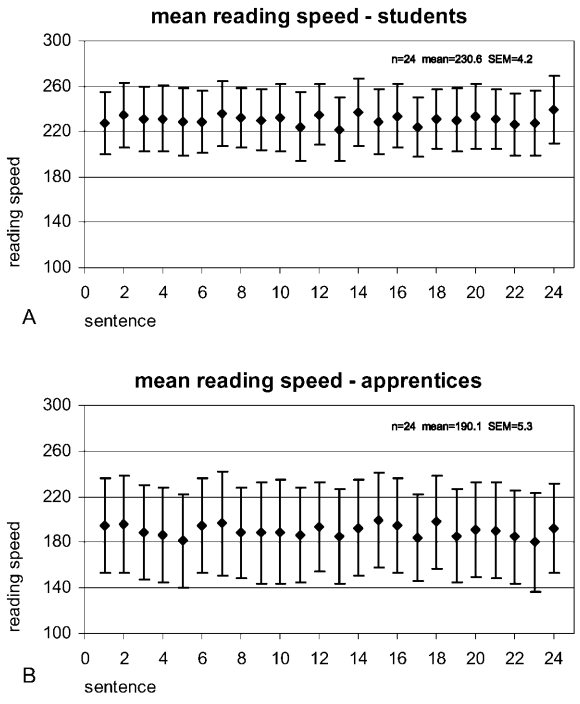


Fig. 2A, B Mean reading speed and standard deviation for the 24 sentences. **A** For the students the mean reading speed varied from 221.9 wpm to 239.1 wpm (mean 230.56±4.2 wpm). **B** For the apprentices it varied from 179.9 wpm to 199.4 wpm (mean 190.1±5.4 wpm)

Table 1 Reading speeds obtained with the short sentences and paragraphs 3, 4 and 5 of the ZRT

Group	Short sentences	ZRT-all	ZRT-3	ZRT-4	ZRT-5
Students (*n*=99)	230±28	191±25	215±29	187±26	170±26
Apprentices (*n*=99)	190±41	147±28	167±32	140±29	133±27
All (*n*=198)	209±41	169±35	191±39	163±36	152±32

Table 2 Number of reading errors per sentence

Group	Short sentences	ZRT-3	ZRT-4	ZRT-5	ZRT-3+4+5
Students (*n*=99)	0.08±0.31	0.49±0.69	1.53 ±1.02	1.15±1.06	1.06±1.03
Apprentices (*n*=99)	0.35±0.68	2.56±2.00	4.43±2.85	3.57±1.81	3.52±2.69
All (*n*=198)	0.21±0.55	1.51±0.81	2.97±2.58	2.36±2.44	2.28±2.37

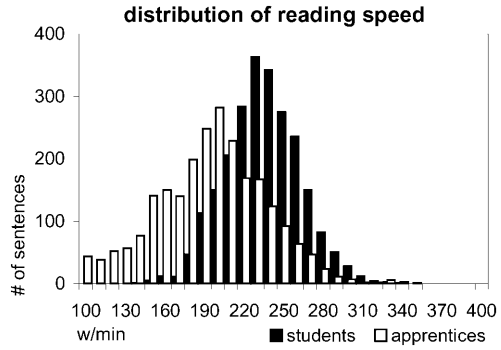
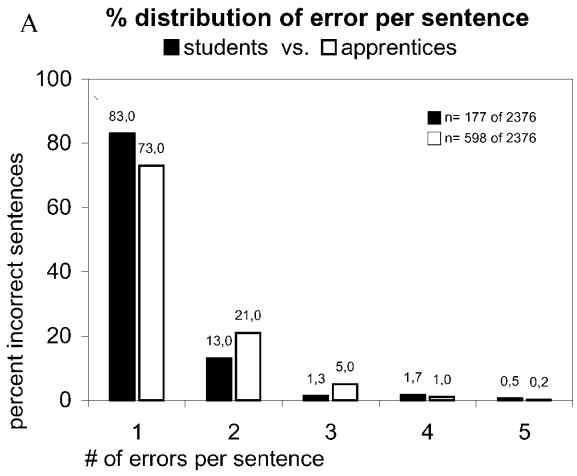


Fig. 3 Reading speed distribution for all 2376 sentences that were read by each group. Compared with the students (*black bars*) the reading speed distribution of the apprentices (*white bars*) was shifted to the left (slower reading speed) and exhibited a higher standard deviation

To assess the validity of the reading speed measurements obtained with our short sentences, we compared these reading speed results to those obtained with the long paragraphs of the standardised ZRT. The reading speed as measured with the ZRT was significantly lower ($P<0.001$) than that obtained with the short sentences, but the correlation between the two methods was very high ($r=0.9$; Tables 1, 3). The reading speed measurements obtained with the ZRT were 147.3±28.3 wpm for the apprentices, 191.4±25.8 wpm for the students and 169.2±5.0 wpm for the two groups together. The reading speed significantly decreased from ZRT-3 to ZRT-5 (Table 1; $P<0.001$). The correlation between the three paragraphs of the ZRT was, however, high (Table 3). Structural analysis of the ZRT paragraphs revealed that the percentage of one-syllable words decreased from ZRT-3 to ZRT-5; conversely, the proportion of words made up of more syllables increased from ZRT-3 to ZRT-5. The syntactical structure of the sentences also increased in complexity.

The reliability analysis for reading speed measurements made with short sentences yielded an overall Cronbach's alpha coefficient of 0.98. The coefficient of selectivity of the 24 sentences (items) varied from 0.75 to 0.88.



errors per sentence	0	1	2	3	4	5
students: # of sentences read	2199	148	23	2	3	1
apprentices: # of sentences read	1778	438	126	27	6	1

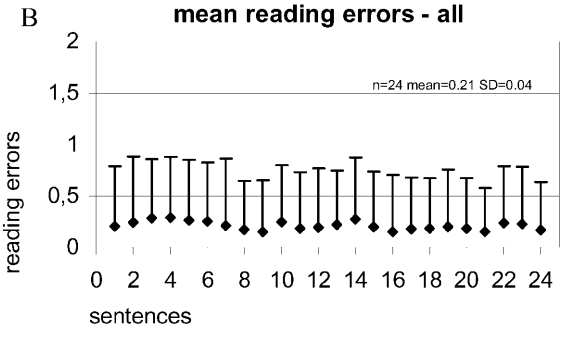


Fig. 4 **A** Distribution of errors per sentence in percent. Up to five errors were made (one sentence per group). A single error was made in most cases. The number of incorrectly read sentences was higher for the apprentices [students: 177 (8%) of 2376; apprentices: 598 (25%) of 2376]. **B** For the two groups together, the mean number of errors per sentence varied from 0.15 to 0.29 (mean 0.21±0.04)

Discussion

Because at present there is no standardised German reading chart for the investigation of reading acuity and speed, our goal was to develop a German reading chart using short single sentences [19], which is reliable, easy

Table 3 Correlations between the various text versions

Group	Pearson's correlation coefficients: reading speed			
	Short sentences and ZRT-all	ZRT-3 and ZRT-4	ZRT-4 and ZRT-5	ZRT-3 and ZRT-5
Students (n=99)	0.618	0.838	0.764	0.804
Apprentices (n=99)	0.896	0.876	0.854	0.904
All (n=198)	0.900	0.914	0.904	0.875

to perform, not time consuming and can be compared with other near vision acuity systems [3, 9, 13, 19].

Legge et al. have shown that reading speed can reliably be measured with single short sentences. Their MNREAD tests have elegantly created a clinically relevant basis for reading speed analyses [2, 9, 13]. In addition, Bailey and Lovie have shown that it is possible to determine reading speed and reading acuity with short phrases in one simultaneous examination [3]. This method has also been applied to the MNREAD acuity charts introduced by Mansfield et al. [13] and to our new reading charts [19], which differ from the MNREAD tests in the approach to several definitions and methodical issues [19]. We believe that when reading speed is determined on the basis of reading acuity it is necessary to use highly comparable sentences (test items). In comparison to Legge et al., who used sentences similar in number of characters and spaces, we developed sentences (test items) that are highly comparable in terms of lexical difficulty, syntactical complexity, word length and position of words, and then standardised these sentences statistically on a group of volunteers. The MNREAD test [9] originally used single sentences consisting of 4 lines and 53 characters, including spaces. For the printed chart version of this test, which was introduced by Ahn et al. in 1995 [2], the same set of sentences was used. In another study, Mansfield et al. [14] used another MNREAD test version to compare the effects of various fonts on reading performance. For the "Times font" version of this test they used sentences consisting of 3 lines and 60 characters (including spaces) and compared these to the "Courier bold" version made of sentences with 4 lines and 56 characters. In addition, in all MNREAD test versions the sentences have a different number (10–14) as well as length and position of words. In contrast for the RR charts we decided to make the sentences as consistent as possible and therefore developed them following highly defined rules, e.g. same number of words (14), same word length and same word position [20; Fig. 1]. The typical word length and word distribution of the German language [5] was taken into consideration. The length of a line was chosen to be between 27 and 29 characters, including spaces because this number was found to be used in many newspaper columns (in light of the wish of our low-vision patients to read newspapers again). The sentences are relative clauses, which is an easy and common syntactical structure in German. To define a set of comparable sentences as test items for the reading charts, we statistically selected the 24 most equal ones among 32 sentences [19]. To our opinion a choice of such test items, which are highly comparable in terms of lexical difficulty, reading length and construction, allows us to optimise the reliability and validity of reading performance analyses when short sentences are used, especially when intended to subsequently use them for analysis of reading acuity.

Ahn and Legge [1] investigated the validity of reading speed measurements using the printed chart version of the MNREAD test. In four groups of 10 visually handicapped patients each who suffered from different diseases, they found that the reading speeds obtained with these charts correlated (r=0.69–r=0.85) with those obtained for long paragraphs of 150 words. These data indicate the validity of reading speed measurements obtained using single sentences in such patients. In the present study we analysed the reliability and validity of reading speed measurements obtained using our short sentences in two large groups of healthy volunteers (n=198), and we found a very high correlation between the reading speeds obtained using these short sentences and those obtained with the long paragraphs of the standardised ZRT. Although the ZRT originally was standardised on 4th- to 6th-grade pupils [11] paragraphs 3, 4 and 5 are similar to our short sentences concerning syntactical structure as well as the percent distribution of words with different numbers of syllables. Another advantage of the ZRT paragraphs was their increasing lexical difficulty, which led to a significant reduction in reading speed from paragraph 3 to paragraph 5 (Table 1). Thus, these paragraphs were well suited to show that the reading speed measured with our short sentences also applies to long paragraphs of varying difficulty. In addition, the high Cronbach's alpha of 0.98 and the high coefficient of selectivity of the 24 sentences, ranging from 0.75 to 0.88, together demonstrate the good reliability of these sentences for reading speed measurements. These sentences should also be well suited as test items for a reading acuity chart, because a decrease in reading speed or an increase in reading errors is now much more likely to be attributable to the print size than to other sentence characteristics.

For the present study we used a stopwatch to measure the reading time in order to calculate the reading speed, a method that is well accepted as reliable for measuring reading speed with single sentences [1, 2, 13, 14, 19]. However, it should be emphasised that an acceptable accuracy of stopwatch measurements depends on the examiner's experience and on the procedure. We therefore seek to improve our stopwatch measurements and have learned to anticipate the vocal onset of a reader by looking for the initial pre-movements of the lips. In addition, we educate examiners as follows: both the experienced and the inexperienced investigator perform measurements simultaneously until their results are constantly comparable. Re-analysing the data obtained by stopwatch measurements with a newly developed computer system [20], we found a high (r=0.939) correlation between the stopwatch measurements and the computer re-measurements. This agreement indicates that the accuracy of our stopwatch measurements is good and reproducible.

Students read 177 (8%) of 2376 sentences with errors, and the apprentices read 598 (25%) incorrectly. Al-

though in most of the sentences only one single error was counted, the number of errors seems to be relatively high for 3rd-grade sentences. Two features of the study design must be responsible for that: (a) we forced the volunteers to read the sentences as fast as possible, and (b) an error was counted even if corrected. Nevertheless, if reading errors are included in a "reading acuity score", it is important that an increase in errors is attributable to changes in print size when the positions of the words and their number of syllables are defined and comparable within the sentences.

In addition, when we compared the reading speeds obtained with each of the three paragraphs of the standardised ZRT, we found that an increase in the number of longer words within a paragraph caused a significant decrease in reading speed. This finding indicates that the reading level of a text is not only correlated with the increasing complexity of the syntactical structure, but also seems to be positively correlated with the proportion of longer words. Thus, the distribution of words exhibiting different numbers of syllables seems to affect the level of the test sentences and the amount of time a person needs to read them. This observation also supports our decision to develop a test-item set of comparable sentences by considering the typical distribution of syllables in German. In addition, we decided to calculate reading speed based on the time necessary to read the sentences as a whole, without excluding the words that were read incorrectly because the words within our sentences are not of the same length.

Stangler-Zuschrott [22] reported a decrease in reading speed in patients suffering from non-exudative age-related maculopathy after 1–2 min of reading a small print size (Courier, 10 point); this decrease, however, was not observed for a larger print size (Courier, 14 point). Although the critical print size, i.e. the print size where the patient's reading speed decreases, can be effectively determined with a reading chart that uses short sentences, this particular phenomenon, which seems to occur just close to or at the critical print size after more than one sentence is read, it is likely to be missed. Thus, not all reading problems will be diagnosed with short sentences, and it seems to be evident that only a clear definition of standardised test items that are optimised for similarity can establish the limits of such unequivocally useful tests. Mackensen and Stichler [12] analysed reading speed by determining the time needed to read the lines of a text written by a famous German author. They reported that the distribution of the mean reading times for highly educated persons was significantly steeper than that for craftsmen. Our results (Fig. 3) confirm Mackensen and Stichler's findings and thus further indicate the validity of reading speed measurements with our standardised sentences.

In the present study we show the definition of a set of German sentences, which are used as test items for our reading charts. These test items have been made highly comparable in terms of lexical difficulty, position and length of words and reading time. Thus, the test items are of almost equal reliability. It is therefore very likely that an increase in reading errors or a decrease in reading speed is caused by changes in print size rather than by sentence characteristics. For clinical and research purposes the simultaneous determination of reading acuity and reading speed in the same examination using standardised test items is a refinement in the diagnosis of reading performance [1, 2, 9, 13, 19]. Comparable reading charts composed of defined test items in different languages would improve diagnosis and facilitate international communication about the reading performance of patients.

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References

1. Ahn S, Legge G (1995) Psychophysics of reading. XIII. Predictors of magnifiers aided reading speed in low vision. Vision Res 35:1931–1938
2. Ahn S, Legge G, Luebker A (1995) Printed cards for measuring low-vision reading speed. Vision Res 35:1939–1944
3. Bailey I, Lovie J (1980) The design and use of a new near-vision chart. Am J Optom Physiol Opt 57:378–387
4. Blankenagel A (1988) Optische und elektronische vergrößernde Sehhilfen: Auswahl, Erprobung und Verordnung. Z Augenspiegel 4:6–13
5. Delattre P (1965) Comparing the phonetic features of English, German, Spanish and French. Groos, Heidelberg
6. Ferris F, Kassoff A, Bresnick G, Bailey I (1982) New visual acuity charts for clinical research. Am J Ophthalmol 94:91–96
7. Friedman S, Munoz B, Rubin G, West S, Bendeen-Roche K, Fried L (1999) Characteristics of discrepancies between self- reported visual function and measuring reading speed. Salisbury Eye Evaluation Project Team. Invest Ophthalmol Vis Sci 40:858–864
8. Hakkinen L (1989) Vision in the elderly and its use in social environment. Scand J Soc Med Suppl 53:5–60
9. Legge G, Ross J, Lybker A, Lamay J (1989) Psychophysics of reading-VIII. The Minnesota low vision reading test. Optom Vis Sci 66:843–853
10. Legge G, Ross J, Isenberg L, La May J (1992) Psychophysics of reading. XII. Clinical predictors of low vision reading speed. Invest Ophthalmol Vis Sci 33:667–72
11. Lindner M, Grissemann H (1968) Zuercher Lesetest. Huber, Bern
12. Mackensen G, Stichler H (1963) Die Untersuchungen der Lesegeschwindigkeit in Abhängigkeit vom Bildungsgrad. Graefe's Arch Ophthalmol 161:81–86

13. Mansfield J, Ahn S, Legge G, Luebker A (1993) A new reading-acuity chart for normal and low vision. Opt Soc Am Techn Digest 3:232–235
14. Mansfield S, Legge G, Bane M (1996) Psychophysics of reading. XV. Font effects in normal and low vision. Invest Ophthalmol Vis Sci 37:1492–1501
15. Massof R (1995) A system model for low vision rehabilitation. I. Basic concepts. Optom Vis Sci 725:725–736
16. Massof R (1998) A system model for low vision rehabilitation. II. Measurement of vision disabilities. Optom Vis Sci 74:349–373
17. Radner W, Huber A, Stolba U, Stur M, Velikay M, Thaler A (1996) Special needs and preferred low vision aids in senile macular degeneration. In: Klaus J, Auff E, Kremser W, Zagler W (eds) Interdisciplinary aspects on computers helping people with special needs. Oldenburg, Vienna, pp 777–780
18. Radner W, Huber A, Thaler A (1997) Visuelle Rehabilitation. I. Vergrößernde Sehhilfen. Wien Med Wochenschr 147:288–290
19. Radner W, Willinger U, Obermayer W, Mudrich C, Velikay- Parel M, Eisenwort B (1998) Eine neue Lesetafel zur gleichzeitigen Bestimmung von Lesevisus und Lesegeschwindigkeit. Klin Monatsbl Augenheilkd 213:174–181
20. Radner W, Obermayer W, Willinger U, Eisenwort B, Velikay-Parel M (2000) A new computerized method for reading speed analysis. Invest Ophthalmol Vis Sci 41(4):436 (abstract 2306)
21. Rubin G, West S, Munoz B, Bandeen-Roche K, Zeger S, Schein O, Fried L (1997) A comprehensive assessment of visual impairment in a population of older Americans. The SEE Eye Evaluation Project. Invest Ophthalmol Vis Sci 38:557–568
22. Stangler-Zuschrott E (1990) Verminderte Lesegeschwindigkeit und rasche Ermüdbarkeit als Zeichen der gestörten Sehfunktion. Klin Monatsbl Augenheilkd 196:150–157
23. Turano K, Geruschat D, Stahl J, Massof R (1999) Perceived visual ability for independent mobility in persons with retinitis pigmentosa. Invest Ophthalmol Vis Sci 40:865–877
24. West S, Munoz B, Rubin G, Schein O, Bandeen-Roche K, Zeger S, German S, Fried L (1997) Function and visual impairment in a population- based study of older adults. The SEE Eye Project. Salisbury Eye Evaluation. Invest Ophthalmol Vis Sci 38:72–82
25. Whittaker SG, Lovie-Kitchin J (1999) Visual requirements for reading. Optom Vis Sci 70:54–65