Improving reading rate prediction with word length information: Evidence from Dutch

Marc Brysbaert Longjiao Sui Wouter Duyck Nicolas Dirix

Department of Experimental Psychology

Ghent University, Belgium

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Address: Marc Brysbaert
 Department of Experimental Psychology
 Ghent University
 B-9000 Gent, Belgium
 Email: marc.brysbaert@ugent.be

Abstract

Previous research in English has suggested that reading rate predictions can be improved considerably by taking average word length into account. In the present study, we investigated whether the same regularity holds for Dutch. The Dutch language is very similar to English, but words are on average half a letter longer: 5.1 letters per word (in non-fiction) instead of 4.6. We inserted the new value in the equation previously proposed for English, and observed how well the outcome matched reading rates of 62 participants reading 12 texts with varying word lengths. Predictions were close to the best fitting curve, indicating that the equation generalises from English to Dutch. The equation predicts that Dutch texts with an average word length of 5.1 letters will be read at a rate of 238 word per minute (wpm). Texts with an average word length of 4.5 letter will be read at 270 wpm, and texts with an average word length of 6.0 letters will be read at a rate of 202 wpm.

A meta-analysis of reading rates revealed that English readers have an average reading speed of 238 words per minute (wpm) for non-fiction and 260 wpm for fiction (Brysbaert 2019). Brysbaert (2019) argued that the difference in reading rate could be predicted by taking mean word length into account. Average word length in English non-fiction texts is 4.6 letters, against 4.2 letters in fiction. By using reading rate for non-fiction as the baseline, reading rate for fiction could be predicted accurately with the equation $Reading\ Rate = 238 * 4.6/4.2$, which gives a value of 261 wpm.

Brysbaert's (2019) equation can be used to improve predictions for individual texts. For instance, in the Nelson-Denny test, participants are asked to read texts silently and answer questions about them. The number of words read in the first minute is taken as an estimate of reading rate. Throughout the years, several editions of the test have been published, known as Forms A, B, ... J. Each form has a slightly different reading rate in the standardization tables. For instance, average reading rate of university students for Form G is 243 wpm, whereas it is 261 wpm for Form H (Brown et al., 1993). On the basis of Brysbaert's (2019) equation, we expect that average word length will be longer in Form G than in Form H. This is indeed the case: average word length of the first five paragraphs of Form G is 4.4 letters (based on 428 words), whereas it is 4.2 letters in Form H (based on 437 words). Using the equation, the predicted reading rates are $238 * 4.6/4.4 = 249$ wpm for Form G, and 261 wpm for Form H, reasonably close to the observed values.

Brysbaert's (2019) equation was based on data published by Carver (1971, 1976), Miller and Coleman (1971), and Coke (1974), who all reported that reading rate expressed as words per minute decreased as a function of text difficulty but not when it was expressed as letters per second or syllables per second. All these authors therefore suggested that wpm should be replaced by letters or syllables per second as a more appropriate measure. Although these variables have been adopted in specialized research areas, they failed to appeal to the wider public (and researchers in general), arguably because they lack the intuitive understanding of wpm.

The present study was designed to investigate whether Brysbaert's (2019) equation can be generalised to Dutch. The Dutch language very much resembles English but has longer words on average. For instance, average word length in the English subtitle corpus SUBTLEX-US (Brysbaert & New, 2009) is 3.76 letters, compared to 4.26 letters in the equivalent Dutch subtitle corpus SUBTLEX-NL (Keuleers et al., 2010). A similar analysis of one million sentences from parallel English and Dutch corpora based on newspaper texts and texts collected from the web (Goldhahn et al., 2012) yielded word lengths of 4.81 in

English in 5.23 in Dutch. On the basis of these data, we can estimate that average word length is about half a letter longer in Dutch than in English, giving the Dutch equation $Reading\ rate = 238 * 5.1/WL$, in which 238 is the average reading rate for non-fiction texts, 5.1 is the average word length in non-fiction texts, and WL is the word length observed in the text for which one wants to estimate reading rate. We use the same base reading rate for Dutch as for English, because there are few indications that reading rates differ between Dutch and English, despite their difference in typical word length. Brysbaert (2019) reported an average silent reading rate of 228 wpm for Dutch non-fiction, but the estimate was based on only 7 studies (against 144 in English).

To increase the comparability of our data with those published in English, we used translations of the materials used by Carver (1971) and Miller and Coleman (1971). These comprised expository paragraphs of 150 words compiled by Miller and Coleman (1967) and published by Aquino (1969). The texts varied in average word length, which correlated with text difficulty (readability).

Method

Participants

Participants were 62 students from Ghent University (mainly undergraduate students; 48 females), reporting no reading problems or other issues that might affect their performance. The present experiment was the last part of a larger reading study that lasted two hours and for which the participants were paid €20.

Stimulus materials

The 36 texts compiled by Miller and Coleman (1967) and published by Aquino (1969) were translated by the first author and checked by comparing the original to the Google back translation. The materials for the present study consisted of 12 texts, selected on the basis of their average Dutch word length, ranging from 4.5 to 6.4 letters (average = 5.3). Average word length of the corresponding English texts was 4.7 (range 4.2 – 5.5). The number of words in the Dutch texts was on average the same as that of the English texts (149 words). Each text was followed by four yes/no questions about the main ideas of the texts (in order not to force the participants to pay undue attention to minor details). The Dutch texts and their

English originals are available at <https://osf.io/ep5fs/>. The main characteristics are summarised in Table 1.

Text presented	Text M&C	English	Letts/word	Dutch	Letts/word
		Nwords		Nwords	
1	16	150	4.2	144	4.5
2	12	150	4.2	148	4.6
3	23	150	4.3	167	4.7
4	31	150	4.7	169	4.8
5	24	150	4.6	161	4.9
6	15	150	4.2	149	5.1
7	27	150	4.9	154	5.3
8	28	150	4.7	137	5.5
9	34	150	5.1	155	5.7
10	26	150	5.0	126	6.0
11	35	150	5.5	143	6.2
12	33	150	5.3	141	6.4
	Average	150.0	4.7	149.5	5.3

Table 1: Characteristics of the texts used: Text number in Miller & Coleman (1967), number of words and average word lengths in the original English texts and in the Dutch translations.

Procedure

Texts were presented on a computer screen. Participants were asked to read the text, shown on a single screen, as they would normally do. They were told that each text would be followed by four yes/no questions, in order to ensure reading for comprehension. No feedback was given about the correctness of the responses. Each participant got a different, random order of the texts. The present experiment happened after a similar experiment also involving text reading and answering questions. This meant that participants had already been reading for more than an hour (with some breaks in-between). Brysbaert (2019) showed that longer testing times lead to more stable results, because participants resort to their habitual reading rate, rather than trying to be overly fast or overly accurate (slow). Time was registered when the text appeared and when participants pressed the bar to answer questions, giving us an indication of text reading time.

Results

Participants answered 87% of the questions correctly (range: 75% - 98%; on a total of 48 questions per person; guessing rate = 50%). Reading times were converted to reading rates expressed as words per minute. Average reading rate was 228 wpm (SD across participants: 55). Differences in reading rates between participants were very stable, with both Cronbach's alpha and McDonald's omega .96.

Figure 1 shows the reading rates for the different texts, ordered by average word length (going from short to long). As expected, reading rate decreased as average word length increased. Pearson correlation between average reading rate and average word length was $-.80$ ($N = 12$), indicating that 64% of the variance in reading rates between texts could be accounted for by average word length.

Figure 1: Reading rate as a function of average word length. Texts ordered from short words (average length = 4.5) to long words (average word length = 6.4). Blue dots indicate the raw data of the participants.

Figure 2 shows the observed reading rates with the predicted values on the basis of the equation $Reading\ rate = 238 * 5.1/WL$, in which 238 is the expected reading rate for texts with word length of 5.1 letters and WL is the word length of the text under consideration. For comparison purpose, the figure also includes the best fitting quadratic function based on the observed values. The a priori predictions were close to the best possible fit. R^2 of the best fitting quadratic function was .66 (compared to .64 for the linear function). R^2 for the a priori predicted values was .62 (based on the squared deviations between the a priori predicted values and the observed values, relative to the total variability in the observed values).

Figure 2: Observed reading rates and 95% confidence intervals for the texts with different word lengths. Also shown are the predictions based on Brysbaert's (2019) equation – thick solid line – and the best fitting quadratic curve – thin dotted line.

Discussion

Reading rate is an interesting variable. It is used to decide about deficient reading in various forms (dyslexia, vision deficiency, slow reading without a clear cause), to gauge the time required for various tasks (most prominently reading assignments), and to test the quality of new presentation devices and letter fonts. Reading rate is also important for psychological theories about the reading processes, individual differences in information processing, language differences, task effects, and metacognition.

Non-specialized researchers (and the general public) have a preference for reading rates expressed as words per minute (wpm), arguably because this variable is easy to understand and to calculate.¹ The preference for wpm goes against the observation that reading rate depends on the length of the words in the text. Various authors (Carver, 1971, 1976; Coke, 1974; Miller & Coleman, 1971) argued that reading rate corrected for word length is a better measure. They proposed letters per second or syllables per second as alternative measures. Carver also suggested to recalculate observed word length to a standardised word length of five letters. None of the alternative measures has had much impact beyond specialised research areas.

Brysbaert (2019) proposed a simple equation to correct reading rate in wpm for differences in word length (WL) and thereby improve predictions for individual texts. The equation started from the observation that, across studies, English reading rate is 238 wpm for texts with an estimated WL of 4.6 letters. By taking the ratio $4.6/WL$, the estimate is adapted for the text at hand. Texts with average WL below 4.6 (fiction, spoken language) result in higher estimates; texts with longer words (scientific texts, some expository texts) result in lower estimates. This allows users to refine predictions for the text at hand, as shown for the Nelson-Denny test in the introduction.

In the present study we investigated whether a similar equation works in Dutch. We started from the observation that Dutch words are on average half a letter longer than English words. As a first approximation, this was the only element we changed in the equation: we assumed a reading rate of 238 wpm for texts with average WL of 5.1 letters (instead of 4.6). As shown in Figure 2, this equation comes so close to the findings that no further adaptations seem to be needed. The equation predicts that Dutch texts with $WL = 4.0$ will be read at a rate of $238 * 5.1/4.0 = 303$ wpm, whereas Dutch texts with $WL = 6.5$ will be read at a rate of $238 * 5.1/6.5 = 187$ wpm.

¹ A simple way to calculate average word length is to use MS Word. Take away all punctuation marks from the text (except for ' and -) and use the REVIEW button to calculate the number of letters without spaces and the number of words. Divide the former by the latter.

To see how well the equation improves predictions for other studies, we can look at data collected by Mak and Willems (2018). These authors asked 109 participants to read three short Dutch stories (between two thousand and three thousand words each), while eye movements were tracked. After each story the participants were asked three general questions to make sure they had read the stories. Reading rate was 304 wpm for the first story, 253 wpm for the second, and 222 wpm for the third. This strongly suggests that the texts differed in average word length. Upon inspection of the materials, that was indeed the case: The respective word lengths were 4.4 letters, 4.5 letters, and 5.1 letters. Based on the equation, the predicted reading rates for the three texts are: $238 * 5.1/4.4 = 276$ wpm, $238 * 5.1/4.5 = 270$ wpm, and $238 * 5.1/5.1 = 238$ wpm. Although the predictions fall short of accounting for the complete range of reading rates observed, they reduce the average prediction error from 32 wpm for the uncorrected reading rate to 20 wpm for the corrected one.

The deviations between observed and predicted reading rates bring us to a final consideration. In the equations we used, we saw that word length considerably improves reading rate predictions for individual texts. This could be because word length itself is an important variable affecting reading speed, or because word length is highly correlated with other variables influencing text readability, such as average word frequency, word age-of-acquisition, sentence length, syntactic complexity, and a rift of other variables (for reviews, see Chen & Meurers, 2016; Crossley et al., 2017; De Clercq & Hoste, 2016). Average word length is an interesting variable because it is straightforward to calculate (and so can be implemented without problem in reading time calculators), but in all likelihood derives a large part of its power from the fact that it is highly correlated with other language-related variables. Further research will have to indicate how much predictions can be improved by taking other text difficulty factors into account. These studies will have to make use of many more texts than the current 12, and of texts that systematically vary the other variables researchers are interested in.

Availability

Texts and data are freely available at <https://osf.io/ep5fs/>.

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