Breaking down the word length effect on readers' eye movements

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Abstract

Previous research on the effect of word length on reading confounded the number of letters (NrL) in a word with its spatial width. Consequently, the extent to which visuospatial and attentional-linguistic processes contribute to the word length effect on parafoveal and foveal vision in reading and dyslexia is unknown. Scholars recently suggested that visual crowding is an important factor for determining an individual's reading speed in fluent and dyslexic reading. We studied whether the NrL or the spatial width of target words affects fixation duration and saccadic measures in natural reading in fluent and dysfluent readers of a transparent orthography. Participants read natural sentences presented in a proportional font that contained spatially narrow and wide four- to seven-letter target words. The participants looked at spatially narrow words overall for a longer duration partially due to more frequent regressions, which showed that crowding can disrupt word recognition during normal reading. In addition, reliable NrL effects on fixation duration suggest that letters are important attentional units during reading. Saccadic measures including relative landing position, refixation and skipping probability were strongly affected by spatial width and slightly affected by the NrL, which suggests that saccadic programming and parafoveal processing of upcoming words are limited by visual acuity more than by attentional factors. The dysfluent readers overall had longer fixation durations for words but did not show larger crowding or NrL effects.

Keywords: reading fluency; eye movements; word length, crowding; word skipping

Longer words require more time to be recognized (e.g., Balota, Cortese, Sergent-Marshall, Spieler, & Yap, 2004; Hautala, Hyönä, & Aro, 2011a; New, 2006; see Barton, Hashim, Eklinder, & Hills, 2014 for a recent review), which is pronounced in developmental dyslexia (e.g., De Luca, Di Pace, Judica, Spinelli, & Zoccolotti, 1999; Hautala, Aro, Eklund, Lerkkanen, & Lyytinen, 2013; Hautala, Hyönä, Aro & Lyytinen, 2011b; Ziegler, Perry, Ma-Wyatt, Ladner & Schulte-Körne, 2003). Generally, the temporal word length effect has been thought to stem from linguistic-attentional processing. However, there are several potent visuospatial explanations for the word length effect, and scholars have suggested that dyslexia may at least partially stem from a visuospatial processing deficit (Martelli, Filippo, Spinelli, & Zoccolotti, 2009; Zorzi, Barbiero, Facoetti, Lonciari, et al., 2012). Further, although during reading saccadic programming of the landing position is mainly based on spatial information about word spaces and fixation durations that reflect word recognition processes of textual information (Hautala et al., 2011a; Infoff, Eiter, Radach, & Juhasz, 2003), direct empirical evidence of how deep this functional dissociation is and whether it holds for all types of saccades, including refixations, regressions and word skips, is lacking. In the present study, for the first time, the spatial width of a word and the number of letters (NrL) were orthogonally manipulated, and their contribution to various eye movement measures of normal and dysfluent reading were examined.

Temporal word length effects are due to visual or perceptual limitations that force readers to make progressive refixations when they read long words (Vergilino-Perez, Collins, & Doré-Mazars, 2004). Human acuity foveal vision covers only two visual degrees, which typically equals six to eight letters (see Rayner, 1998), and acuity degrades rapidly in the parafovea. The size of the perceptual span in reading has been studied with a gaze-contingent display technique such as the moving window paradigm in which the number of upcoming letters visible to a reader is manipulated (see Rayner, 1998). These studies have shown that people learn to recognize letters that extend from foveal vision to the reading direction. The perceptual span increases during reading development (Häikiö, Hyönä, Bertram, & Niemi, 2009) so that fluent adult readers can identify seven to eight letters forward (McConkie & Rayner, 1975; see Rayner, 1998 for a review), while poor readers have a smaller span (Bosse, Tainturier, & Valdois, 2007; Hautala & Parviainen, 2014; Häikiö et al., 2009; Rayner, 1983). Reading is partly serial phonological decoding, a skill that becomes automatic during elementary school (Zoccolotti, De Luca, Di Filippo, Judica, & Martelli, 2009) but remains difficult for children with developmental dyslexia (Share, 1995; Wimmer, 1993, 1996a,b; Zoccolotti, De Luca, & Di Pace, 2005). When reading short words, the word length effects (New, 2006) of a single fixation (Hautala et al., 2011a,b) may also reflect attentional serial letter processing during word recognition (Coltheart, Rastle, Perry, Langdon, & Ziegler, 2001; Perry, Ziegler, & Zorzi, 2007; see especially Hawelka et al., 2010). In addition, problems in phonological decoding or whole-word recognition may explain the difficulty with reading that children with developmental dyslexia experience and their distinctive eye movement behavior during reading, including longer fixations, more frequent refixations and regressions and shorter saccades (see Bellochi, Muneaux, Bastien-Toniazzo, & Ducrot, 2013, for a recent review).

However, word length effects could reflect visuospatial processing. The leading models of eye movement control in reading assume that the speed of letter recognition increases by the distance of the letter from the fixation point (e.g., Engbert, Nuthmann, Richter, & Kliegl, 2005; Radach & Reilly, 2006; Reichle, Pollatsek, & Rayner, 2006), which is called here as the *visual acuity hypothesis for letter encoding*. In principle, this process may be responsible for the temporal word length effects within foveal vision, and deficits in this process may contribute to larger word length effects in readers with dyslexia. In contrast, *visual crowding* (Bouma, 1970, 1973), which is the degradation of the spatial frequency of vision as a function of eccentricity, impairs perception of nearby objects in peripheral and parafoveal vision. Pelli, Tillman, Freeman, Su, Berger, and Majaj (2007) provided extensive evidence that reading is essentially achieved within an uncrowded span that roughly equals the foveal vision and the perceptual span, beyond which the crowding makes identifying letters impossible. Visual interference of very near objects (< .1 visual degrees) within foveal vision is called foveal crowding (Levi, Klein, & Hariharan, 2002). Although this concept is controversial (Huurneman, Boonstra, Cox, Cillessen, & van Rens (2012), visually more densely packed words may be harder to read and lead to increased fixation times.

Regarding dyslexia, Martelli and colleagues (2009) found that children with dyslexia showed larger crowding effects in a peripheral letter identification task, and the magnitude of this crowding effect was associated with individual differences in reading speed. Bellochi et al. (2013) reported similar findings in a subgroup of individuals with dyslexia. Providing further support for the idea of a visual processing deficit in at least a subgroup of individuals with dyslexia, scholars recently reported that individuals with dyslexia showed abnormalities in several low-level oculomotor skills including binocular coordination (for a review, see Bellochi et al., 2013; Gori & Facoetti, 2015). Recent research reports that increasing letter and word spacing improve reading speed in children with dyslexia (Perea, Panadero, Moret-Tatay, & Gómez, 2012; Zorzi, Barbiero, Facoetti, Lonciari et al., 2012). Zorzi and colleagues (2012) suggested that wider letter spacing may help children with dyslexia focus on each letter during the phonological decoding process.

Word spaces and word length are important determinants of saccadic behaviors such as landing position (where to fixate on the word) and whether to skip or refixate a word (for a complete review of saccadic behavior during reading, see Rayner, 1998 and Schotter, Angele, & Rayner, 2012). Saccades are planned toward the preferred viewing location slightly left of the word center, which provides optimal visibility of the words. Corrective refixations toward the word center are made after mislocated fixations due to oculomotor error. If the word is long and extends over the foveal vision, the initial fixation location shifts to the word beginning, and the probability of making a progressive refixation increases, which suggests that refixations may even be preplanned according to word length information in the parafovea (Vergilino-Perez et al., 2004). Very short words are often skipped, especially when the preceding fixation is near, presumably because they fall within the acuity vision and can be parafoveally identified to a sufficient degree. Skipped words are then regressed more often because the parafoveal recognition may have been erroneous or words were skipped by accident due to oculomotor error in saccade targeting. Regressions are also made due to challenges in reading comprehension. Generally, this body of knowledge is almost exclusively based on studies that manipulated word spaces and word length in text presented in a monospaced font. Therefore, whether attentional or perceptual span (NrL), or visual (spatial width) factors are responsible for these saccadic effects, or both is not actually known. In addition, whether parafoveal preprocessing affects the landing position and the probability of skipping a word is governed by attentional or visual acuity limitations are not known (Schotter et al., 2012).

Some studies have been conducted on visuospatial influences on readers' eye movements. One method for studying these influences involves manipulating fonts and letter spacing. Rayner, Slattery, and Bélanger (2010) used the moving window technique to investigate whether letter spacing of proportional and monospaced fonts influences readers' eye movements. Although the researchers observed no effects on the perceptual span in the number of words, the decreased letter spacing led to a faster overall reading rate via the decreased number of fixations and their duration, but the number of regressions increased. In a follow-up study in which Slattery and Rayner (2013) manipulated letter spacing, text presented with standard letter spacing yielded the fastest reading times relative to the decreased or increased letter spacing condition. The authors also observed benefits in the average fixation duration for decreased letter spacing when the word spacing was increased, which suggested crowding effects were present at the letter and word levels during reading. Regarding font effects, Rayner et al. (2010) did not find an overall difference in reading rates; however, in Slattery and Rayner's study the proportional font was read faster than the monospaced font. A common finding for both studies and our previous study (Hautala et al., 2011a) is that proportional fonts tend to be read with fewer but longer fixations than monospaced fonts, which suggests two contrasting factors affect reading: While more letters in a proportional font fall in acuity vision, crowding is increased by the shorter distance between the letters.

However, in contrast, Perea and Gomez (2012) found that slightly expanded letter spacing provided weak benefits for reading speed and average fixation durations, but larger expanded spacing resulted an increased number of fixations per word. Perea and Gomez also found the initial fixation locations shifted to the word beginning when the letter spacing was expanded, but Slattery and Rayner (2013) did not confirm this finding. One possible reason for these conflicting findings across letter spacing and font studies is that manipulating letter spacing leads to unfamiliar typography for a reader, which may have consequences of its own for readers' eye movements.

In an early study, Morrison and Rayner (1981) studied eye movements when individuals read identical text at varying viewing distances. The researchers found viewing distance had no effect on saccade amplitude in letters, which led the researchers to conclude that attentional, not visual, factors determine how many letters are processed during a fixation. However, fixation durations were longer at larger viewing distances, suggesting that visual factors affect how efficiently letters are recognized.

Recently, Miellet, O'Donnell, and Sereno (2009) compensated for the degradation of visual acuity by magnifying parafoveal letters accordingly. The researchers assumed that if the perceptual span were limited by visual acuity, parafoveal magnification would improve parafoveal letter recognition and lead to increased perceptual span. This manipulation did not increase the perceptual span measured by varying the size of the moving window, which led the authors to suggest that the perceptual span is limited by attention, not visual acuity. We believe it is difficult to draw any firm conclusions about normal reading from such an unnatural reading condition; however, reading with and without parafoveal magnification seemed to be surprisingly similar. The authors agreed that providing their participants more training with such an unnatural reading condition may have made improvements in reading possible.

McDonald (2006) rendered all words in a text with an equal spatial width and compared eye movement measures with six- and eight-letter target words. He found that temporal fixation duration measures that reflected word recognition including first, single fixation and gaze durations and a saccadic measure of refixation probability were influenced by the NrL, whereas most of the saccadic measures, including skipping probability, landing position and launch distance, were not affected by the NrL in a word.

Hautala et al. (2011a) compared two NrL effects: the one controlled by spatial width by taking advantage of variability in letter widths (e.g., "m" and "i," mama vs. flight) when presented in a proportional font and the NrL effect with spatial width confounded when presented in a monospaced font. Again, the NrL affected the fixation duration measures, and spatial width affected only the saccadic measures. Refixation probability was almost significantly affected by spatial width, not by the NrL as McDonald found. However, both studies had shortcomings. McDonald (2006) studied words rendered unnaturally with equal spatial width, which led to visually unnatural crowded words. Hautala et al. (2011a) confounded font type with spatial width manipulation.

In the present study, we optimized the experimental design by comparing reading of narrow and wide four- to seven-letter words, all presented in the same proportional font. By manipulating the orthography of the words' spatial width and the number of letters, we aimed to resolve whether fixation duration and saccadic word length effects on readers' eye movements result from the visual (spatial width) or attentional (NrL) level of processing, and whether these effects are associated with reading fluency. According to the attentional view, the fixation duration and saccadic effects (except landing position) should be based on the NrL. According to the visual acuity hypothesis, the fixation durations should be longer for wider words, and the saccadic measures should reflect the increased processing demands of wide words (less skipping and more refixations and regressions). According to the visual crowding hypothesis, the fixation durations should be longer, and the saccadic measures should reflect the increased processing demands of narrow words that contain more objects in a given space. Dysfluent readers were expected to show generally increased fixation durations and more frequent refixations and regressions, and possibly a larger influence of NrL and crowding on these measures.

Materials and methods

Apparatus

An SMI Hispeed eye tracker with a 500 Hz sampling rate was used to record the eye movements of the participants' right eye. The computer screen (size 375 × 300 mm, resolution 1024 × 768 pixels) was located 670 mm from the participant's eye.

Participants

The participants were 37 native Finnish-speaking young adults (age $M = 20$, $SD = 4.8$ years). They were recruited by sending an email to the student mailing lists of local high schools, a vocational university and a university. In the letter, students with and without reading problems were invited to participate in the study. A written informed consent was obtained from the participants before their participation. The experiment was undertaken in accordance with the Declaration of Helsinki. The ethical committee of the University of Jyväskylä approved the research protocol. The participants' reading skills were assessed with text reading and word list reading subtests from an assessment battery for reading disabilities (Nevala, 2007). In the text reading subtest, the participant score was the number of words read aloud within a 3 min time limit. The word list reading subtest participant's score was the time taken to read aloud the 30-item word list. The participant was considered a dysfluent reader (DYS, $N = 11$) if he or she scored below the 11th percentile in population on either the text (controls 366 words, DYS 295 words, $t(32) = 5.3$, $p < .001$) or word reading subtask (controls 22.2 s, DYS 36.5 s, $t(32) = 7.3$, $p < .001$) while the other participants constituted the control group of fluent readers. The participants' IQ was assessed with the standard progressive matrices test (SPM test; Raven, Raven, & Court, 1998). One participant was excluded from the analysis due to a poor score on the SPM test, after the groups had equal IQs, $t < .62$, and another was dropped due to an incomplete measurement. Participants received movie tickets as compensation for their participation. Eye tracking of one participant was not possible due to her tendency to keep her eyes half closed. Thus, our total sample was 34.

Target words and sentences

To study the independent influences of the spatial width of a word, and the NrL in a word, narrow words that contain several narrow letters such as "l," and wide words that contain several wide letters such as "m" were selected as the target words. Each category of wide and narrow four- to seven-letter words contained 20 words, for a total of 160 target words. The visual and psycholinguistic descriptions of the stimuli are presented in Table 1, and the entire list of the stimulus sentences is in the Aappendix A. The categories were controlled for word and bigram frequency, based on a large newspaper text corpus of lemma frequencies (Language Bank of Finland, 2007). The number of orthographic neighbors was also controlled except between four- and seven-letter words since longer words have unavoidably fewer word neighbors in Finnish. The target words were embedded in 80 sentence beginnings, paired as follows: 1) narrow four-letter and wide seven-letter words, 2) wide four-letter and narrow seven-letter words, 3) narrow five-letter and wide five-letter words, and 4) narrow six-letter and wide six-letter words. A comparison of pairs 1 and 2 would reveal whether the NrL effect is a similar size when the spatial width of the words is the same (i.e., controlled) vs. very different (i.e., not controlled), whereas separate analyses of pairs 3 and 4 would reveal whether spatial width has an effect when the NrL is controlled. Pairs 3 and 4 could not be included in the same analysis since narrow five- and six-letter words and wide five- and six-letter words had different spatial widths. For the same reason and because of the differing sentence frames, we did not evaluate the main effect of spatial width in the analysis of pairs 1 and 2.

Word pairs were formed so that they shared the same part of speech (nouns with nouns, etc.) and that they had semantic likeness within a word pair. Examples of the stimuli embedded in the envelope sentences are shown in Figure 1. We constructed sentences with long words around the target word to minimize pre- and post-target word skipping. An online survey (Limesurvey; Schmitz, 2010) was used to evaluate the predictability, plausibility and emotional charge of the sentences, and there were no differences in these qualities within sentence pairs, *F*s < .1. Predictability was established with the standard cloze probability procedure. Plausibility evaluation was performed by presenting the sentence pair to the survey participants and asking whether sentence 1 was more plausible, or sentence 2 was more plausible, or the sentences were equally plausible. Emotional charge was evaluated by asking the survey participants whether sentence 1 evoked emotional reaction, sentence 2 evoked emotional reaction, both sentences evoked emotional reactions, or neither sentence evoked emotional reaction.

Figure 1. Sample sentence pair. Sentence translates literally "To my greatest misfortune binoculars/egg broke after falling from the table," with "binoculars" and "egg" being the target words.

Mitä suurimmaksi epäonnekseni kiikari hajosi pudottuaan pöydältä.
Mitä suurimmaksi epäonnekseni muna hajosi pudottuaan pöydältä.

Table 1. Mean spatial width in degrees, word frequency in a million words, number of word neighbors and bigram frequency in a thousand words of target word categories with standard deviations in parentheses.

Comparison	Spatial width controlled		Not controlled		Five-letter words		Six-letter words	
Letters	Four	Seven	Four	Seven	Narrow	Wide	Narrow	Wide

Spatial width	1.47	1.49	.93	2.18	.96	1.44	1.45	2.06
	(.08)	(.10)	(.06)	(.22)	(.09)	(.08)	(.07)	(.17)
Word	34	98	144	105	112	73	192	155
frequency	(69)	(210)	(154)	(95)	(117)	(96)	(578)	(286)
Word	2.90	.55	3.50	.50	2.15	3.00	1.15	1.40
neighbors	(1.94)	(.944)	(2.33)	(.89)	(1.93)	(1.97)	(1.22)	(1.09)
Bigram	1.7	3.0	5.9	4.1	5.5	5.3	5.4(4.8)	6.2
Frequency	(2.2)	(2.6)	(5.0)	(2.9)	(3.0)	(3.7)		(3.4)

Procedure

Participants leaned their head against a forehead and chin rest. A 13-point calibration procedure was repeated at the beginning of the experiment and after every 40 sentences, and was repeated if the deviation between the calibration and the validation was more than 0.2 degrees. Each trial started with the requirement to look a fixation cross at the left edge of the upper half of the screen for 500 ms, which triggered the stimulus sentence to appear. After the participant read the sentence, he or she fixated for 500 ms on a fainter fixation cross at the right edge of the screen, which triggered the sentence to disappear. Sentences were presented in the proportional font Calibri at 16 points (see Table 1 for the visual degrees of the stimuli words). After 24 specific sentences, a yes or no question about the previous sentence appeared, and the participants were instructed to answer by choosing the correct alternative with the mouse. All 160 sentences were randomized for every participant.

Data processing

Fixations were detected with the saccade–velocity-based algorithm developed by the eye tracker manufacturer (SMI). The area of interest was analyzed and the dependent measure was calculated with the manufacturer's analysis package for reading studies. The parameters for detecting a saccade were a saccade velocity threshold of 40 °/s and a minimum saccade duration of 22 ms; however, these parameters left some anomalies to saccadic amplitude data so saccades that exceeded 150 pixels in length were excluded from further analyses (56 cases). Fixations shorter than 50 ms and longer than 1000 ms were excluded from further analysis.

Data analysis

The following target word–specific measures that reflect word recognition processes were selected: Total fixation duration and first-pass gaze duration reflected the overall and first-pass word recognition processes, respectively. Single-fixation duration included occurrences when a word was recognized by one fixation. To study the influence of manipulated variables on eye movement control, saccading measures including relative landing position (percentages of a word's horizontal width) and refixation, skipping and regression probabilities were analyzed. In the within-subject F1 analyses, these measures were the subject of repeated measures analysis of variance with two-level within-subject factors of the NrL (four, seven) and spatial width (controlled, not controlled) in the analysis of four- and seven-letter words. In this analysis, we were not interested in the main effect of spatial width (as it was presented in different sentence pairs) but in the possible interaction of spatial width and the NrL. In the analyses of five- and six-letter words, there was a two-level spatial width factor (narrow, wide). A two-level between-subject factor of reading fluency (CONTROLS, DYS) was used in each analysis. Significant interactions were inspected with paired *t*-tests. In the F2 item analysis of four- and seven-letter words, there were two-level within-subject factors of NrL (four, seven) and Group (CONTROLS, DYS) and a two-level between-subject factor of spatial width (controlled, not-controlled). In the F2 analyses of five- and six-letter words, there was a two-level within-subject factor of spatial width (narrow, wide) and Group (CONTROLS, DYS).

The three analysis blocks were used to test the following hypotheses: If narrow words induced values that reflected increased processing demands, the crowding hypothesis was supported. If wider words induced values that reflected increased processing demands, the visual acuity hypothesis was supported. If spatial width had no influence but the NrL did, the letters as cognitive processing units hypothesis was supported.

Results

The means for all measures are given in Tables 2 and 3 separately for fluent and dysfluent readers. Only significant F1 and F2 effects or significant F1 effects with non-significant F2 result of particular interest are reported. The complete ANOVA tables are provided in the Appendix B. The groups did not differ in answering the comprehension control questions, $F < 1$; the DYS group answered the questions with accuracy 94.3% accuracy, and the controls with 93.1% accuracy.

Table 2. Means and standard deviations for eye movement measures for fluent readers.

Comparison	Spatial width controlled				Spatial width not controlled				Five-letter words				Six-letter words			
	Four-letter		Seven-letter		Four-letter		Seven-letter		Narrow		Wide		Narrow		Wide	
	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD
Single fixation duration	253	49	266	54	240	47	263	63	250	64	231	44	266	53	256	48
Gaze duration	259	46	277	52	242	45	280	64	251	55	236	45	266	51	272	50
Total fixation duration	309	74	337	75	288	66	333	93	326	88	270	60	342	102	323	77
Refixation probability	25	16	31	16	21	13	31	18	25	16	18	15	32	19	30	15
Regression probability	14	12	14	8	15	10	10	6	16	10	7	5	17	13	10	8
Relative landing position	58	7	52	9	58	8	45	7	58	9	57	9	55	8	48	6
Skipping probability	14	15	7	6	28	23	2	5	29	21	9	11	9	13	3	6

Table 3. Means and standard deviations for eye movement measures for dysfluent readers.

Comparison	Spatial width controlled				Spatial width not controlled				Five-letter words				Six-letter words			
	Four-letter		Seven-letter		Four-letter		Seven-letter		Narrow		Wide		Narrow		Wide	
	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD
Single fixation duration	288	79	323	95	280	74	291	92	294	68	252	66	287	90	292	85
Gaze duration	295	79	334	96	286	71	315	93	293	64	288	78	302	90	316	85
Total fixation duration	383	95	451	162	375	130	429	127	406	72	353	104	425	135	391	132
Refixation probability	39	15	40	19	30	15	46	17	31	17	30	15	39	16	35	15
Regression probability	15	8	14	9	18	11	14	9	18	6	10	6	18	9	9	8
Relative landing position	55	10	52	12	59	10	46	11	60	7	55	11	55	11	52	11
Skipping probability	9	13	4	5	26	15	3	6	24	17	9	10	9	9	5	13

Influence of orthogonal manipulation of spatial width and NrL

Single fixation duration

The NrL had a main effect, $F1(1, 32) = 8.264$, $p = .007$, $\eta_p^2 = .205$, $F2(1, 38) = 3.196$, $p = .082$, $\eta_p^2 = .078$; seven-letter words received longer fixation durations than four-letter words (286 vs. 265 ms).

Gaze duration

The NrL had a main effect, $F1(1, 32) = 24.112$, $p < .001$, $\eta_p^2 = .430$, $F2(1, 38) = 17.984$, $p < .001$, $\eta_p^2 = .321$; seven-letter words received longer fixation durations than four-letter words (302 vs. 270 ms).

Total fixation duration

The NrL had a main effect, $F1(1, 32) = 20.515$, $p < .001$, $\eta_p^2 = .391$, $F2(1, 38) = 9.730$, $p = .003$, $\eta_p^2 = .204$, seven-letter words received longer fixation durations than four-letter words (339 vs. 387 ms). The main effect of Group, $F1(1, 32) = 8.189$, $p = .007$, $\eta_p^2 = .204$, $F2(1, 38) = 96.930$, $p < .001$, $\eta_p^2 = .718$, indicated that overall the DYS group looked at the target words longer than the controls (409 vs. 317 ms).

Refixation probability

The main effect of NrL, $F1(1, 32) = 14.998$, $p = .001$, $\eta_p^2 = .319$, $F2(1, 38) = 10.327$, $p = .003$, $\eta_p^2 = .214$, was accompanied by the two-level interaction of Width x NrL, $F1(1, 32) = 6.226$, $p = .018$, $\eta_p^2 = .163$, $F2(1, 38) = 2.733$, $p = .107$, $\eta_p^2 = .067$. This interaction resulted from the increase in refixation probability, when spatial width was not controlled for (from .25 to .38; $t(33) = -4.40$, $p < .001$) but not when it was controlled (from .32 to .36; $t(33) = -1.67$, $p = .104$). The main effect of Group, $F1(1, 32) = 5.851$, $p = .021$, $\eta_p^2 = .155$, $F2(1, 38) = 44.129$, $p < .001$, $\eta_p^2 = .537$, indicated that overall the DYS group made more refixations than the controls (.39 vs .27, respectively).

Relative landing position

The main effect of the NrL, $F1(1, 32) = 60.548$, $p < .001$, $\eta_p^2 = .654$, $F2(1, 38) = 51.577$, $p < .001$, $\eta_p^2 = .576$, was accompanied by the two-level interaction of Width x NrL, $F1(1, 32) = 23.872$, $p < .001$, $\eta_p^2 = .427$, $F2(1, 38) = 10.964$, $p = .002$, $\eta_p^2 = .224$. This interaction resulted from a shift in the relative landing position to the word beginning in seven- vs. four-letter words when spatial width was not controlled for (from 58% to 46%; 9.08, $p < .001$), relative to when it was controlled (from 56% to 52%; 4.09, $p < .001$).

First-pass skipping probability

The main effect of the NrL, $F1(1, 32) = 38.991$, $p < .001$, $\eta_p^2 = .549$, $F2(1, 38) = 220.850$, $p < .001$, $\eta_p^2 = .853$, was accompanied by two-level interaction of Width x NrL, $F1(1, 32) = 29.165$, $p < .001$, $\eta_p^2 = .477$, $F2(1, 38) = 76.681$, $p < .001$, $\eta_p^2 = .669$. This interaction resulted from the larger decrease in the probability of skipping as a function of the NrL when spatial width was not controlled for (.27 to .02; $t(33) = 7.42$, $p < .001$) relative to when it was controlled (.12 vs .05; $t(33) = 3.44$, $p = .002$).

Ten point two percent of the word skips to narrow words were likely overshoots shown as missing tails in landing position distribution. Although this value was subtracted from the skipping probability in the narrowest word category (narrow four- to five-letter words), the effect of spatial width on word skipping remained highly significant, $F(1,34) = 14.6$, $p = .001$, $\eta_p^2 = .307$, when compared to wide four- and five-letter words.

Summary

There was a reliable NrL effect of 18 ms per letter on the total fixation duration measure, and a 10 ms per letter -effect in single fixation duration -measure, yet this latter effect was only a trend-like in item-analysis. Skipping and refixation probability and landing position were clearly affected by spatial width, with the exception that the effect in refixation probability was not significant in item analysis. These variables were also slightly affected by the NrL, since words with a higher NrL and wider words were landed more toward the word beginning, refixated more often and skipped less often than narrower or shorter words. The DYS group was associated with longer total fixation duration and more frequent refixations.

The effect of spatial width

Single fixation duration

In five-letter words, the main effect of Width, $F1(1, 32) = 14.837$, $p = .001$, $\eta_p^2 = .317$, $F2(1, 19) = 15.744$, $p = .001$, $\eta_p^2 = .453$, resulted from the longer fixation duration on narrow (272 ms) vs. wide words (241 ms).

Gaze duration

In five-letter words, the main effect of Group, $F1(1, 32) = 5.621$, $p = .024$, $\eta_p^2 = .149$, $F2(1, 19) = 33.649$, $p < .001$, $\eta_p^2 = .639$, resulted from longer durations for the DYS group (291 ms) relative to the controls (243 ms).

Total fixation duration

In five-letter words, the main effect of Width, $F1(1, 32) = 15.561$, $p < .001$, $\eta_p^2 = .327$, $F2(1, 19) = 7.540$, $p = .013$, $\eta_p^2 = .284$, resulted from longer durations for narrow (366 ms) vs. wide (312 ms) words. The main effect of Group, $F1(1, 32) = 9.755$, $p = .004$, $\eta_p^2 = .234$, $F2(1, 19) = 24.572$, $p < .001$, $\eta_p^2 = .564$, resulted from longer durations for the DYS group relative to the controls (379 vs. 298 ms). In six-letter words, the main effect of Width, $F1(1, 32) = 7.059$, $p = .012$, $\eta_p^2 = .181$, $F2(1, 19) = 2.022$, $p = .171$, $\eta_p^2 = .096$, resulted from longer durations for narrow (384 ms) vs. wide words (357 ms).

Regression probability

In five-letter words, the main effect of Width, $F1(1, 32) = 23.635$, $p < .001$, $\eta_p^2 = .425$, $F2(1, 19) = 8.385$, $p = .009$, $\eta_p^2 = .306$, resulted from the higher regression probability for narrow (.17) vs. wide (.08) words. In six-letter words, the main effect of Width, $F1(1, 32) = 12.165$, $p = .001$, $\eta_p^2 = .275$, $F2(1, 19) = 7.283$, $p = .014$, $\eta_p^2 = .277$, resulted from the higher regression probability for narrow (.17) vs. wide (.09) words.

The narrow words might have been regressed because they were skipped more often (20.5% vs. 10.6% of trials). However, the same pattern of results was present when the analysis of the regression probability was restricted to non-skipping trials, which suggests that the regression probability findings were not only consequences of skipping for five-letter words, $F1(1, 32) = 17.1$, $p < .001$, $\eta_p^2 = .341$, and six-letter words, $F1(1, 32) = 13.7$, $p = .001$, $\eta_p^2 = .294$.

Relative landing position.

In five letter words, the effect of width only approached significance, $F1(1, 32) = 3.940$, $p = .056$, $\eta_p^2 = .110$, $F2(1, 38) = 4.228$, $p = .054$, $\eta_p^2 = .182$. Wider words were landed more towards word beginning (55 %) than narrow words (59 %).

In six letter words, the effect of width was highly significant, $F1(1, 32) = 40.612$, $p < .001$, $\eta_p^2 = .559$, $F2(1, 38) = 15.9$, $p = .001$, $\eta_p^2 = .456$. Wider words were landed more towards word beginning (50 %) than narrow words (55 %).

First-pass skipping probability

In five letter words, the effect of width was highly significant, $F1(1, 32) = 29.915$, $p < .001$, $\eta_p^2 = .483$, $F2(1, 38) = 68.413$, $p < .001$, $\eta_p^2 = .783$. Narrow words were skipped more often than wide words (0.26 vs. 0.09, respectively)

In six letter words, the effect of width was significant, $F1(1, 32) = 5.390$, $p = .027$, $\eta_p^2 = .144$, $F2(1, 38) = 7.255$, $p = .014$, $\eta_p^2 = .276$. Narrow words were skipped more often than wide words (0.8 vs. 0.04, respectively)

Summary

Narrow vs. wide five-letter words were fixated on longer in the single fixation duration and total fixation duration measures and regressed more often, and narrow vs. wide six-letter words were regressed more often and had longer total fixation durations in subject but not in item-analysis. However, these effects were substantially weaker than in five-letter words. The DYS group was associated with overall longer fixation durations in five-letter words in the gaze duration and total fixation duration measures. Similarly what was found in orthogonal analysis of spatial width and NrL, skipping probability and landing position were strongly governed by spatial extent of words.

Discussion

We studied how spatial width and the NrL in the target words affect eye movement measures during typical and dysfluent reading. We found that the total fixation durations (the sum of the durations of all fixations on a word) on narrow words were somewhat higher than those for wide words, which suggests that visual crowding in foveal vision may increase fixation durations, not visual acuity limitations, when individuals read relatively short words fit mostly on foveal vision (only the wide six- and seven-letter words were wider spatially by more than two degrees). This finding is in line with recent findings that visual crowding is an important factor in reading (Martelli et al., 2009; Pelli et al., 2007; Perea & Gomez, 2012; Slattery & Rayner, 2013; Zorzi et al., 2012). The crowding in our data partially resulted from more frequent regressions to narrow words, which suggests that crowding disrupts word recognition during first-pass reading, and thus, the readers had to return to check the word. This finding agrees with two recent reports on increased regression rates for text presented in decreased letter spacing (Rayner et al., 2010; Slattery & Rayner, 2013).

The crowding effect on fixation durations was especially strong in five-letter words but much weaker in six-letter words. Narrow five-letter words may have been perceptually the most challenging because they consisted of similar visual letters with high spatial frequency, for example*, tilli* (dill), whereas the most narrow six-letter words were somewhat less crowded because they consisted of letters of more variable width, for example*, piikki* (spike). This suggests that not only the letter spacing but possibly also the distance between letter center points or, in general, the overall discriminability of letters within words counts when it comes to visual processing of words. This view is in accordance with the recent understanding of the multilevel nature of crowding (Whitney & Levi, 2011). Overall, we conclude that the effect of visual crowding can be substantial, but only among very densely packed words. Further, visual and lexical processes may also interact if the visually challenging word has visually similar word neighbors, such as *tilli/tiili* (dill/brick). Although the number of orthographic neighbors between narrow and wide words was controlled in this study, future studies should investigate additional specific interplays between visual crowding and lexical processes.

In line with our previous study (Hautala et al., 2011a), there was a consistent NrL effect in summative fixation duration measures. In gaze duration, there was an NrL effect but no crowding effect, indicating that these effects can occur independently of each other. However, the NrL effect on words with equal spatial width can result from crowding since there are more objects in the given space, while the NrL effect on words with various spatial widths may result from refixations. Therefore, the single fixation duration measure may be the purest measure for comparing crowding and NrL effects. This is justified also from the viewpoint that visual effects should appear early during the time course of word processing, and therefore be present already in single-fixation duration. The results in this variable indicated the NrL effects were similar irrespective of whether the spatial width was controlled (a crowded condition) or not, suggesting that this effect was due to the NrL, not crowding. The temporal word length effect resulted mainly from the genuine NrL effect, whereas particularly crowded words seemed to provide an extra visual challenge for a reader. Thus, we believe letters are important attentional units in reading. However, letters of very familiar words may be processed in parallel (Coltheart et al., 2001; Perry et al., 2007); thus, the NrL effect may be even absent (see Hawelka et al., 2010 for a recent eye movement study).

The saccadic measures were heavily influenced by the spatial width of the word but also slightly by the NrL. The landing position shifted to the word beginning, refixations were more frequent and skipping was less frequent for wider and longer (NrL) words. Generally, this pattern of findings is in line with the view that spatial instead of linguistic information is predominantly used for saccade targeting while linguistic information is mainly used for word recognition processes (Inhoff et al., 2003). However, this finding suggests that this functional dissociation is not all or nothing, but linguistic-attentional demands of the upcoming word are used to fine-tune the saccade targeting. Since the number of letters is a factor in word recognition that consistently affects fixation times, the saccadic system is also affected by this processing demand to some extent: Words with fewer NrL could be more easily recognized parafoveally and thus skipped, and landing more toward the word beginning of words with more letters prioritizes processing of the word beginning (Hautala & Parviainen, 2014) and leaves more space for progressive refixation saccades (Vergilino-Perez et al., 2004).

The strong influence of spatial width on saccadic measures is most likely caused by visual acuity limitations. If a word is spatially wide, the initial saccade lands more toward the word beginning to provide a high-quality visual sample of the word beginning, while refixations may be done to provide a higher-quality visual sample of the word ending. Similarly, very narrow words may be skipped because they are within reach of the foveal vision from the previous fixation location and could therefore be parafoveally identified. Such identification, however, is futile as shown by generally more frequent regressions to skipped words. Further, the effect of spatial width on the skipping rate depends on some currently unspecified typographical factor, since Slattery and Rayner (2013) did not find clear effects of increased or decreased letter spacing (which affects words' spatial width) on the skipping rate, yet skipping occurred more frequently on a spatially more condensed proportional vs. spatially wider monospaced font in their study. The finding that spatial width has an important role in parafoveal processing in landing position and skipping (see also Hautala et al., 2011; McDonald, 2006) contradicts the view that the parafoveal preprocessing of words is mainly limited by attention, not visual acuity (Miellet et al., 2009; Schotter et al., 2012). Our results do not favor any models of eye movement control in reading (Engbert et al., 2005; Reilly & Radach, 2006; Reichle et al., 2006) but suggest that visual acuity limitations should be stressed over attentional limitations in processing of upcoming words.

In regards to reading fluency, dysfluent readers had overall longer fixation durations, and made more refixations. Since reading speed was not consistently associated with the effect of spatial width on temporal eye movement measures, we conclude that crowding was not related to reading fluency in our sample of adult readers. In contrast to several developmental studies (De Luca et al., 1999; Hautala et al., 2011b; Hutzler & Wimmer, 2004; Hyönä & Olson, 1995), but in line with a study with adult readers with dyslexia (Hawelka et al., 2010), dysfluent readers showed only insignificant trends toward a larger NrL effect. However, this is not to say that specific visual or letter-processing deficits could not be found in a subgroup of individuals with dyslexia suffering from problems in visual processing (Bellochi et al., 2013) or generally in readers who are more affected than the dysfluent readers studied here. In more severely affected readers, disturbances in letter processing are more likely to be detected (Moll, Hutzler, & Wimmer, 2005).

In conclusion, the present results support the view that letters are important attentional units in processing of foveally fixated words while visually very crowded words require longer viewing time to be correctly identified and still must be regressed in some cases. However, neither the NrL nor the crowding effect was associated with reading fluency in our data. Our results also provide strong new evidence that all saccadic behavior is more strongly governed by a visual (spatial width) rather than attentional (NrL) factor. Very narrow words within the reach of acuity vision while fixating on the preceding word can be parafoveally identified and skipped, while spatially wide words are landed on more toward the word beginning and refixated more often, presumably to attain a high-quality visual sample of the word beginning and end.

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Appendix. List of stimuli sentences with their alternative target words and sentence endings, separated by bolding and backlash.

Pair 1 - wide four letter vs. narrow seven letter words.
Tummuneiden ikkunoiden vuoksi **aamu näytti synkemmältä kuin se oli** / keittiö näytti synkemmältä kuin se oli
Matin toissapäivänä ostaman uuden talon **amme osoittautui hyvin suureksi /** kellari osoittautui hyvin suureksi
Vaarini kertoo, että vanhoina hyvinä aikoina **hame valmistettiin pehmeästä silkistä** / laituri valmistettiin paksusta männystä
Toistuvista poistoyrityksistä huolimatta **home olikin tarttunut seinään pysyvästi** / juliste olikin tarttunut seinään pysyvästi
Syksyn kylmyyden yllättäessä **hymy hyytyi Pekan huulilta /** viisari hyytyi Pekan mittarista
Pirteän kummipoikani piirtämä **maha sattui olemaan varsin suuri /** kirjain sattui olemaan varsin koukeroinen
Johtokunnan suosituksesta epäonnistunut **maku jätettiin kehitysasteelle** / poliisi jätettiin eläkkeelle tehtävistään
Luonnontieteellisessä museossa **mato herätti eniten kiinnostusta /** tiikeri herätti eniten kiinnostusta
Onnistuneen markkinoinnin vuoksi **mehu myytiin nopeasti** /liiteri myytiin nopeasti
Illasta erittäin railakkaaksi yltynyt **meno loppui poliisien saapuessa/** tiistai loppui poliisien saapuessa
Huonon kuntonsa ja parittomuutensa vuoksi **mono heitettiin roskalavalle/** luistin heitettiin roskalavalle
Poliisin huomion kohteeksi joutunut **mopo päätettiin lopulta pysäyttää/** turisti päätettiin lopulta pidättää
Mitä suurimmaksi epäonnekseni **muna rikkoutui tiputtuaan pöydältä**/ kiikari rikkoutui tiputtuaan pöydältä
Epähuomiossa lattialle jäänyt **muru päätyi hiiren vatsaan/** siivilä päätyi kirpputorille
Huomasin, että aamiaisena pelkkä **namu jättäisi ankean nälän tunteen**/ pilleri jättäisi ankean nälän tunteen
Tilanteen ollessa erittäin kriittinen **oksa varoitti räsähdyksellä katkeamisestaan /** juristi varoitti asiakastaan puhumasta
Tarkastuksessa omituisen näköinen **papu herätti erityistä huomiota/** siviili herätti erityistä huomiota
Tehokkaan suoriutumisensa vuoksi **pomo palkittiin bonuksilla/** tutkija palkittiin bonuksilla
Lukuisien vuosien saatossa **sumu alkoi vähentyä kylän mailta/** viljely alkoi vähentyä kylän mailta
Tyhmän ja ajattelemattoman käskyn aiheuttama **uhma yllätti johtajiston täysin**/ riitely yllätti johtajiston täysin

Pair2 - narrow four letter vs. wide seven letter words.
Kovassa kuumuudessa työskennellessä **hiki pääsi yllättämään**/ vahinko pääsi yllättämään
Pienen tovin kuluttua olikin **ilta koittanut juhlissamme/** kuolema koittanut potilaalle
Vastoin aiempaa käsitystäni **joki kuuluu kansalliseen suojeluohjelmaan**/ maisema kuuluu kansalliseen suojeluohjelmaan
Biologien tutkimusten mukaan **keli vaikuttaa nopeasti kasvien kasvuun**/ kosteus vaikuttaa nopeasti kasvien kasvuun
Jännittävässä kilpailussa viimeinen **kilo osoittautui raskaimmaksi /** laukaus osoittautui raskaimmaksi
Tiedemiesten laskelmien mukaisesti **kivi osoittautui varsin painavaksi /** aurinko osoittautui varsin vanhaksi
Yleensä vilkkailla markkinoilla jokainen **kori saadaan myytyä /** makkara saadaan myytyä
Ammattilaisten mukaan tasapainoinen **koti vaikuttaa lapseen positiivisesti** / rakkaus vaikuttaa lapseen positiivisesti

Taiteilijan kuuluisimmassa maalauksessa **kylä lepää tunturin juurella /** hevonen lepää tunturin juurella
Liikuntakeskuksen runsaasti käytetty **latu vaatii paljon huoltoa** / katsomo vaatii säännöllistä huoltoa
Nuorien vieraiden kovassa käytössä **lelu yllättäen hajosi** / summeri yllättäen hajosi
Viime perjantaina kovassa kiireessä **liha unohtui viikonlopuksi pöydälle** / hakemus unohtui viikonlopuksi pöydälle
Taitavan ruuanlaittajan käsissä **lohi muuttuu herkulliseksi ruuaksi** / hedelmä muuttuu herkulliseksi jälkiruuaksi
Ollin mielestä vaalean keltainen **olut sattuu olemaan maukkain /** kuutamo sattuu olemaan kaunein
Perinteinen Afrikan tähti olikin **peli parhaimmasta päästä!** / kokemus parhaimmasta päästä!
Oppikirjojen mukaan muinaisina aikoina **piru aiheutti runsaasti pelkoa** / ukkonen aiheutti runsaasti pelkoa
Useiden tuntien etsinnän jälkeen **raja löytyi metsän keskeltä /** vastaus löytyi tietosanakirjasta
Markkinoilla palkintoja voittanut **sika myytiin ennätyshintaan** /maalaus myytiin ennätyshintaan
Päätöksen mukaisesti puolueen **väri vaihdettiin toiseen** / ehdokas vaihdettiin toiseen
Heti alusta asti tiesin ettei yleisin **öljy sopisi autoosi!** /näkemys sopisi yleisöllesi!

Pair3 - wide vs. narrow five letter words.
Olohuoneen seinässä näytti olevan **aukko johtuen rikkinäisestä digikamerasta** /pilvi johtuen roskasta dikikameran linssissä
Matti tiesi, että valtion lakiin säädetty **eläke tuli maksaa aina kuun alussa** / tulli tuli maksaa aina yli viiden kilon kuormasta
Juhlissa tarjottavaksi varattu **kahvi loppui nopeasti kuokkavieraiden saavuttua** /viini loppui nopeasti kuokkavieraiden saavuttua
Karjalle tuhoisin eläin näyttäisi olevan **karhu aiheuttamiensa vammojen vuoksi** / hiiri aiheuttamiensa tautien vuoksi
Rakennusmestarin mukaan myrskyn rikkoma **katto täytyisi kunnostaa mahdollisimman pian** / tiili täytyisi vaihtaa mahdollisimman pian
Perinteeksi muotoutunut jokavuotinen **kerho tuottaa merkittävästi varoja kyläyhteisölle** / ralli tuottaa merkittävästi varoja kyläyhteisölle
Menneisyydessä kotien lämmönlähteenä käytetty **koivu tuotti paljon energiaa** / hiili tuotti paljon hiukkaspäästöjä
Lopulta osallistuneiden kyllästyttyä **lakko purkautui kaikessa hiljaisuudessa** /piiri purkautui eri puolille pihaa
Päinvastaisista odotuksista huolimatta **lento olikin nopeasti ohi** /leiri olikin nopeasti ohi
Ostoslistan hukkumisen vuoksi **maito unohtui kauppaan, mikä myöhemmin harmitti** /riisi unohtui kauppaan, mikä myöhemmin harmitti
Suuressa punaisesta laatikosta löytyi **matto vaikka Matti muuta väitti** /siili vaikka Matti muuta väitti
Myrskyn aikana seurakunnan varjeltu **metsä kärsi merkittäviä vaurioita /** risti kärsi merkittäviä vaurioita
Aamulla löysin pienen linnun **niska vaurioituneena ikkunan alta** / siipi vaurioituneena ikkunan alta
Tuomariston mukaan paras lastenkirja olikin **paksu satukirja hattupäisen kissan seikkailuista** /villi satukirja hattupäisen kissan seikkailuista
Maantieteellisen läheisyyden vuoksi **perhe asettui länsirannikolle** / kieli asettui länsirannikolle
Pojallesi eilen ostama punainen **pyörä pitää kammottavaa meteliä /** pilli pitää kammottavaa meteliä
Aikakausilehden tilaajalahjana tullut **reppu tuotti karvaan pettymyksen** / liite tuotti karvaan pettymyksen
Huomasin kesäkuun loppuessa, että **ruoho olikin jo polvenkorkuista** / riihi olikin yllättäen luhistunut
Tarkoista varotoimista huolimatta **ruoka meni pilalle loppuviikosta** / liike meni konkurssiin loppuviikosta

Pair 4 - wide vs. narrow six letter words.
Heti seuraavalla hetkellä **silmä tarkentui merellä kulkevaan laivaan** / litra marjoja oli hävinnyt parempiin suihin
Eilen illalla Maunon kipeytynyt **hammas alkoikin särkemään entistä enemmän** / lantio alkoikin särkemään entistä enemmän
Ruokaa tuottavan yrityksen kallis **kamera rikottiin yön aikana** / portti rikottiin yön aikana
Maija yllättyi huomatessaan, että **kangas täytyisi viedä pesulaan kuivapesuun /** turkki täytyisi viedä pesulaan puhdistettavaksi
Matin vanhassa kotitalossa odotti **karmea kellari hämähäkkeineen** / tilava kellari hämähäkkeineen
Kuulin, että Helsingin pörssissä **kauppa loppui jännittävässä vaiheessa** /viikko loppui jännittävässä vaiheessa
Pitkän ja kuuman työpäivän jälkeen **kuorma osoittautui liian raskaaksi** / leikki osoittautui liian raskaaksi
Toisin kuin huhu kertoi, maatalosta ostettu **lammas olikin kovin kallista** / sokeri olikin kovin kallista
Kylän rautakaupasta löytyi halpa **lamppu keittiöstä rikkoutuneen tilalle** / veitsi keittiöstä hukkuneen tilalle
Läheisen baarin asiakaskunnan mukaan **markka menetettiin poliittisen huijauksen takia** / voitto menetettiin ensimmäisessä erässä
Kokin viime tingassa lisäämä **mauste valitettavasti pilasi ruokalajin** / sipuli valitettavasti pilasi ruokalajin
Odotuksien mukaisesti herkullinen **munkki nousi kahvipisteen hittituotteeksi** / keitto nousi ruokapisteen hittituotteeksi
Maaliskuussa aavikolta esiin kaivettu **muumio tuotti museolle hyvät kävijämäärät** / piikki tuotti nuorelle arkeologille pettymyksen
Kuvaamataidon tunnilla askarreltiin **naamio Kaapon suureksi harmiksi** / lautta Kaapon suureksi harmiksi
Yöllisen tietokonevian vuoksi Leenan **numero katosi väliaikaisesti luettelosta** / osoite katosi väliaikaisesti luettelosta
Elinan isoisän mielipiteen mukaan **näkymä olisi kerrassaan upea** / kielto olisi kerrassaan raivostuttava
Muistatko, kun viime kesänä **pumppu kuulosti kuin se olisi ollut hajoamassa** / soitto kuulosti kuin se olisi tullut nauhalta
Yllättäen kovan äänen kuuluessa **salama räjähti takapihalla rikkoen keinun** / kallio räjähti takapihalla rikkoen keinun
Lehden mukaan näytelmän laimea **sanoma tuotti yleisölle suuren pettymyksen** / tanssi tuotti yleisölle suuren pettymyksen
Kuulin. että maailmanmestarin eilinen **temppu yllätti jokaisen katsojan** / ottelu yllätti jokaisen katsojan
Valheellisissa lupauksissa tarjottu **vapaus sattuu olemaan yleinen palkinto höynäytetylle** / taivas sattuu olemaan yleinen palkinto höynäytetylle

Appendix B.

Complete ANOVA tables for each of the dependent variables. Abbreviations: W = Width, NrL = Number of Letters, G = Group. Degrees of freedom are 1, 32 for all subject analyses (F1), and 1, 38 for item (F2) analysis of NrL x Width, and 1, 19 for item analysis of spatial width in five and six letter words.

Single Fixation Duration							
Analysis	Factor	*F1*	*p*	η_p^2	*F2*	*p*	η_p^2
NrL x W	NrL	8.264	.007	.205	3.196	.082	.078
	G	3.387	.075	.096	65.810	.000	.634
	WxNrL	0.498			1.395	.245	.035
	WxG	0.871			1.915	0.174	0.048
	NrLxG	0.114			1.007	0.322	0.026
	WxNrLxG	2.890	.099	.083	2.596	.115	.064
Five-letter	W	14.837	.001	.317	15.744	0.001	0.453
	G	2.585	.118	.075	17.090	.001	.474
	WxG	2.009	.166	.059	3.353	0.083	0.15
Six-letter	W	0.137			0.048		
	G	1.624	0.212	0.048	18.274	0	0.49
	WxG	0.927			1.257	0.276	0.062

Gaze duration							
Analysis	Factor	*F1*	*p*	η_p^2	*F2*	*p*	η_p^2
NrL x W	NrL	24.112	.000	.430	17.984	.000	.321
	G	3.923	.056	.109	89.387	.000	.702

	WxNrL	0.218			0.057		
	WxG	0.650			0.007		
	NrLxG	0.253			0.106		
	WxNrLxG	2.544	.121	.074	4.178	.048	.099
Five-letter	W	1.856	.183	.055	1.763	.200	.085
	G	5.621	.024	.149	33.649	.000	.639
	WxG	0.438			0.452		
Six-letter	W	1.880	.180	.055	0.727		
	G	3.198	.083	.091	26.556	0	0.583
	WxG	0.313			0.418		

Total fixation duration

Analysis	Factor	*F1*	*p*	η_p^2	*F2*	*p*	η_p^2
NrL x W	NrL	20.515	.000	.391	9.730	.003	.204
	G	8.189	.007	.204	96.930	.000	.718
	WxNrL	0.009	.924	.000	0.049		
	WxG	0.250	.876	.001	0.088		
	NrLxG	1.223	.277	.037	0.455		
	WxNrLxG	1.140	.294	.034	1.384	.247	.035
Five-letter	W	15.561	.000	.327	7.540	.013	.284
	G	9.755	.004	.234	24.572	.000	.564
	WxG	0.020			0.113		
Six-letter	W	7.059	.012	.181	2.022	.171	.096
	G	4.110	.051	.114	40.618	.000	.681

	WxG	0.564			0.243		

First-pass skipping probability

Analysis	Factor	*F1*	*p*	η_p^2	*F2*	*p*	η_p^2
NrL x W	NrL	38.991	.000	.549	220.850	.000	.853
	G	0.312			2.579	.117	.064
	WxNrL	29.165	.000	.477	76.681	.000	.669
	WxG	1.702	.201	.050	1.585	.216	.040
	NrLxG	0.377			2.463	.125	.061
	WxNrLxG	0.044			0.139		
Five-letter	W	29.915	.000	.483	68.413	.000	.783
	G	0.331			1.833	.192	.088
	WxG	0.514			1.138	.300	.056
Six-letter	W	5.390	.027	.144	7.255	.014	.276
	G	0.142			1.058	.317	.053
	WxG	0.258			0.359		

Refixation probability

Analysis	Factor	*F1*	*p*	η_p^2	*F2*	*p*	η_p^2
NrL x W	NrL	14.998	.001	.319	10.327	.003	.214
	G	5.851	.021	.155	44.129	.000	.537
	WxNrL	6.226	.018	.163	2.733	.107	.067
	WxG	0.002			0.022		
	NrLxG	0.054			0.027		
	WxNrLxG	1.583	.217	.047	1.415	.242	.036

Five-letter	W	2.218	.146	.065	1.262	.275	.062
	G	3.326	.078	.094	5.877	.025	.236
	WxNrL	0.757			.944		
Six-letter	W	1.438	.239	.043	0.799		
	G	1.214	.279	.037	5.659	.028	.229
	WxNrL	0.251			0.198		

Regression probability

Analysis	Factor	*F1*	*p*	η_p^2	*F2*	*p*	η_p^2
NrL x W	G	0.476			1.522	0.255	0.039
	NrL	2.169	0.151	0.063	1.55	0.221	0.039
	WxNrL	2.504	0.123	0.073	1.466	0.233	0.037
	WxG	1.898	0.178	0.056	1.698	0.2	0.43
	NrLxG	0.011			0.004		
	WxNrLxG	0.102			0.221		
Five-letter	W	23.635	.000	.425	8.385	.009	.306
	G	1.359	.252	.041	2.014	.172	.096
	WxG	0.089			0.134		
Six-letter	W	12.165	.001	.275	7.283	.014	.277
	G	0.004			0.002		
	WxG	0.294			0.454		

Relative landing position

Analysis	Factor	*F1*	*p*	η_p^2	*F2*	*p*	η_p^2
NrL x W	NrL	60.548	.000	.654	51.577	.000	.576

	G	0.007			0.316		
	WxNrL	23.872	.000	.427	10.964	.002	.224
	WxG	1.973	.170	.058	1.058	.310	.027
	NrLxG	0.556			1.149	.291	.029
	WxGxNrL	0.451			0.056		
Five-letter	W	3.940	.056	.110	4.228	.054	.182
	G	0.019			0.299		
	WxG	1.071	.309	.032	2.400	.138	.112
Six-letter	W	40.612	.000	.559	15.900	.001	.456
	G	0.693			2.382	.139	.111
	WxG	3.682	.064	.103	1.980	.175	.094