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Parafoveal magnification: Visual acuity does not modulate the perceptual span in reading

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Research Article

Parafoveal magnification:

Visual acuity does not modulate the perceptual span in reading

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Running head: Visual and attentional constraints in reading

Abstract

Models of eye guidance in reading rely on the concept of the perceptual span – the amount of information perceived during a single eye fixation, considered a consequence of visual and attentional constraints. To directly investigate attentional mechanisms underlying the perceptual span, we implement a new reading paradigm – parafoveal magnification (PM) – that compensates for how visual acuity drops off as a function of retinal eccentricity. On each fixation and in real time, parafoveal text is magnified to equalize its perceptual impact with concurrent foveal text. Experiment 1 demonstrates that PM does not increase the amount of text that is processed, supporting an attentional-based account of making eye movements in reading. Experiment 2 tests a contentious issue within competing models of eye movement control and shows that, even when parafoveal information is enlarged, visual attention is allocated in a serial fashion from word to word in reading.

During reading, the eyes remain stationary for brief periods called fixations (typically 200-250 ms) during which visual information is extracted. Fixations are punctuated by short (6-8 character) and rapid (~25 ms) movements called saccades. Making eye movements is necessary due to visual acuity and attentional limitations. The perceptual span is defined as that region of text from which useful information can be extracted (for a review, see Rayner, 1998). The relative contributions of visual and attentional constraints which give rise to the perceptual span in reading are underspecified. Our work explores these issues and interprets them in light of current models of eye guidance in reading.

The visual field is functionally divided into three areas based on acuity limitations: the fovea, parafovea, and periphery. In reading experiments (Balota & Rayner, 1991), the foveal region, the central 2^{o} of visual angle around fixation where visual acuity is maximal, generally encompasses 6-8 characters. The parafoveal region, from 2-5^{o}, extends beyond the foveal region to about 15-20 characters, and the peripheral region includes everything beyond 5^{o}.

The perceptual span has been functionally approximated from "moving window" studies (McConkie & Rayner, 1975): text *outside* a window defined around the fixated letter is altered in some way (e.g., valid text is replaced by strings of Xs). When parafoveal preview of upcoming text is invalid, reading time is slowed. For English, the perceptual span is estimated to extend from 3 characters to the left of fixation (approx. the beginning of the fixated word) to 14 characters to the right of fixation. The span's asymmetry is not hard-wired but instead reflects attentional demands linked to reading direction: in Hebrew (where reading direction is right-to-left), the perceptual span extends further to the left (Pollatsek, Bolozky, Well, & Rayner, 1981).

The perceptual span plays a key role in models of eye guidance in reading. The assumption that on-going cognitive processing is a principal determinant of eye movement control (Rayner, Sereno, & Raney, 1996) is the central feature of current models. Models differ, however, in how visual attention is allocated, exemplified by their differing accounts of parafoveal preview benefit (i.e., the fixation time advantage on a word when parafoveal information obtained from the prior fixation is valid vs. invalid; Rayner, 1975). In "sequential attention shift" (SAS) models, parafoveal preview benefit is due to a covert, serial movement of attention towards the parafoveal word preceding the eye movement to that word (e.g., Morrison, 1984; E-Z Reader of Reichle, Rayner, & Pollatsek, 2003). In "guidance by attentional gradient" (GAG) models, the preview benefit is explained by parallel processing of several words within the perceptual span (e.g., SWIFT of Engbert, Nuthmann, Richter, & Kliegl, 2005; Mr. Chips of Legge, Hooven, Klitz, Mansfield, & Tjan, 2002; Glenmore of Reilly & Radach, 2003).

SAS and GAG models can be discriminated by the presence of parafoveal-on-foveal effects – in which the ease or difficulty of processing word *n+1* begins to emerge on word *n* (Drieghe, Brysbaert, & Desmet, 2005; Inhoff, Eiter, & Radach, 2005; Kennedy & Pynte, 2005; Richter, Engbert, & Kliegl, 2006). SAS models cannot account for pervasive parafoveal-on-foveal effects while GAG models can. The existence of such effects, however, is vigorously contested. Inconsistent parafoveal-on-foveal findings may be the consequence of the relative slowness of parafoveal versus foveal processing. That is, such effects may emerge in certain experimental contexts depending, for example, on the eccentricity of parafoveal information, the lexical properties of foveal and parafoveal words, and the readers' skill.

In short, while on-going cognitive processing drives the eyes through text, the amount of information available on any given fixation is constrained by the perceptual span which, in turn, is determined by acuity and attentional limitations. Moreover, how attention is allocated is the main point of debate between current models of eye guidance in reading. In an early reading study, Morrison and Rayner (1981) manipulated acuity by varying the viewing distance to the text. Although they showed that saccade length (in characters) remained constant across changes in the number of characters per degree of visual angle, acuity and attentional demands were confounded. Our approach sought to neutralize the effects of acuity drop-off in order to investigate attentional processes more directly.

Our work addresses two key questions: (1) Is the perceptual span a window of text mainly constrained by visual acuity or attentional resources? and (2) Can enhanced parafoveal information promote parafoveal-on-foveal processing? To explore these questions, we implemented a novel paradigm – called *parafoveal magnification* (PM) – changing the display on every fixation, contingent on the reader's eye position. In PM, text size is enlarged as a function of its eccentricity from fixation, compensating for the relative reduction of parafoveal versus foveal acuity. Specifically, for every eye fixation in reading, displayed text is modified contingent on the reader's fixation location such that parafoveal information is magnified, functionally equalizing its perceptual impact with concurrent foveal information. The paradigm is graphically depicted in Figure 1.

Insert Figure 1 about here

Nazir, Jacobs, and O'Regan (1998) investigated the identification of single words using a similar "butterfly" manipulation to study the relationship between reading time on a word and fixation location. Despite using a magnification function, a viewing position effect remained. However, because single words were presented in isolation, this study cannot adequately address how visual attention is allocated in natural, dynamic, text reading. Indeed, the most efficient viewing position in single word identification ("optimal viewing position"; O'Regan & Jacobs, 1992) is more central than that found in normal reading – one situated between the beginning and middle of the word ("preferred viewing location"; Rayner, 1979). This suggests that the rightward bias of the perceptual span (in left-to-right languages) is due to attentional asymmetry which occurs in fluent reading, but not in single word identification. To our knowledge, our study is the first using gaze-contingent parafoveal magnification to investigate natural reading.

Two experiments were performed using the PM paradigm. The first experiment sought to determine the relative contributions of visual and attentional constraints in parafoveal processing. If parafoveal processing is mostly limited by visual acuity, then magnification of parafoveal letters should facilitate parafoveal processing. In fact, if eye movements in reading are made solely to compensate for visual acuity drop-off, then PM sentences could be read with a single fixation. Alternatively, if the perceptual span is the consequence of attentional limitations – with more resources allocated to the text around fixation and less parafoveally – then the pattern of fixations should be similar to that observed in reading normal text. Single-line sentences were read in normal or PM "font". We additionally manipulated window size for both fonts (a no-window condition, and window conditions of 7-characters to the left with 21-, 14-, or 7-characters to the right), replacing letters outside the window with Xs. Global measures of reading behavior were analyzed. Releasing the constraints of visual acuity through PM allowed us to assess whether the perceptual span itself could be enlarged.

The second experiment explored whether parafoveal-on-foveal effects could be obtained when reading with PM. Magnifying parafoveal information should facilitate parafoveal pre-processing, thus maximizing the opportunity to observe parafoveal-on-foveal effects. Demonstrating such effects would lend support to GAG models. If, however, no such effects were observed within this parafoveally-enhanced context, SAS models would be upheld.

Method

Participants

A total of 60 native English speakers (mean age=24; 37 females) were paid to participate in the experiments, 40 in Experiment 1 and 20 in Experiment 2. All had normal or corrected-to-normal vision.

Apparatus

Eye movements were monitored via an SR Research Desktop-Mount Eyelink 2K eyetracker, with a chin/forehead-rest. The eyetracker has a spatial resolution of 0.01^{o} and eye position was sampled at 1000 Hz using corneal reflection and pupil tracking. Text was presented on a Dell P1130 19" CRT with black letters on a white background. Viewing was binocular with eye movements recorded from the right eye. At a viewing distance of approximately 72 cm, 3 characters of non-magnified text (25 pixels) subtended 1^{o} of visual angle. The CRT was run at 170 Hz and updating the display, contingent on gaze position, took 8 ms on average.

PM implementation

The goal of PM was to perceptually equate parafoveal and foveal information. We progressively magnified parafoveal text, increasing font size for each successive letter outside the foveated letters. Each sentence display was calculated and updated on-line in order to assign a different size and position for each character depending of the fixation location in the sentence. The size increase function was taken from Anstis (1974) who showed that, as the distance from the fovea increases, stimulus size needs to be enlarged to be perceived equally well. Anstis' original equation is y=(0.046)*x, where y is the letter size, and x is the visual eccentricity in degrees. We chose a factor of 0.069 (1.5 times the original) in order to ensure a clear parafoveal identification advantage. Finally, we maintained the "center of gravity" of text across all letters, such that the middles of all letter bodies were aligned. In this way, eye movements programmed to the center of an enlarged parafoveal letter would land on the center of the now-foveal, small letter. The software was written in MatLab (R2006a), using the Psychophysics (PTB-3) and Eyelink Toolbox extensions (Brainard, 1997; Cornelissen, Peters, & Palmer, 2002; http://psychtoolbox.org/).

Materials and design

Experiment 1. There was a total of 160 single-line experimental sentences. Sentences were either presented in normal or PM font. Additionally, sentences were presented in one of four "window" conditions: no-window, or a window of 21, 14, or 7 characters. This led to 8 sets of 20 sentences counterbalanced across four participant groups, each consisting of 10 participants. Sentences sets were roughly equated for length (with a maximum of 60 characters), number of words, and difficulty. The window size corresponded to the number of characters to the right of fixation (in normal or PM font) that were visible; characters outside this window were presented as Xs (in normal or PM font). In the 21-, 14-, or 7-character window conditions, the leftward extent of the window was held constant at 7 characters.

Experiment 2. There was a total of 100 experimental sentences, all of which were presented with PM. These sentences were used in a prior study conducted both in English and in French (Miellet, Pernet, O'Donnell, & Sereno, 2007) which had manipulated the overall plausibility and component word frequencies of adjective-noun phrases. The noun phrase (NP) was either Plausible (P) or Less Plausible (LP). The frequency of adjectives and nouns were either high frequency (HF) or low frequency (LF). The result of crossing NP plausibility (P,LP) by adjective frequency (HF=204 occurrences per million, LF=4) by noun frequency (HF=277, LF=7) gave rise to eight conditions. Word frequency values were obtained from the 90-million written word British National Corpus (BNC; http://www.natcorp.ox.ac.uk). Natural log values were also calculated (the standard measure in models of eye movement control). Across all conditions, target word length was similar (average=5.8 characters). The 100 sentences comprised 10 sentences in six conditions and 20 in both the P-HF-HF and P-HF-LF conditions (for counterbalancing reasons in the original study).

Contextual constraint for P and LP NPs were determined via three indices. The first was a measure of predictability, a Cloze task in which 10 participants were asked to generate a word following a sentence fragment up to, but not including, the target NP. They were then told what the actual word was (the adjective), and were asked to generate another word to follow this augmented sentence fragment. Responses were coded as “1” for a correctly guessed word and “0” for other responses (adjective: P=.015, LP=.000; noun: P=.117, LP=.005). The second index of contextual constraint was a plausibility task in which a different set of 20 participants were asked to rate the plausibility of the NP (adjective-noun) on a 7-point scale (1=low to 7=high plausibility; P=6.08, LP=3.50). The third index was the transitional probability values (based on the BNC; http://corpus.byu.edu/bnc/) of the NP – the conditional probability of the noun given the adjective (P=0.017, LP=0.000).

<u>Procedure</u>

Both experiments involved initial calibration of the eyetracker, reading practice sentences, recalibration, and reading experimental sentences. The experimenter could check the accuracy of the calibration at any time and recalibrate if necessary. Each trial began with a central fixation cross. Fixating this cross triggered the presentation of another cross located at the left, marking the first character position of the sentence. When the eyetracker detected a successful fixation here, a sentence was presented. After reading each sentence, participants fixated another cross at the bottom right of the screen which cleared the display.

In Experiment 1, each block of 20 sentences was preceded by 5 practice items presented under identical display conditions so that participants could become accustomed to each condition. Yes-no comprehension questions followed 80 of the 160 sentences to ensure participants were paying attention (94% correct). In Experiment 2, participants initially read 30 practice sentences with PM. Thirty of the 100 experimental sentences were followed by yes-no comprehension questions (92% correct).

Results

Experiment 1

Three eye movement measures were analyzed across participants: (1) total sentence reading time in seconds; (2) saccade length in pixels; and (3) saccade length in characters. We performed pairwise comparisons (16 in total) for each measure. First, we compared normal versus PM font reading for each of the 4 experimental conditions (no-window, 21-, 14-, or 7-character window). We also compared – within each font type (normal or PM) – each condition to the other conditions (6 comparisons for each font). For each contrast, we calculated p_{rep} (Killeen, 2005) and effect size (d) based on a bootstrapping procedure (5000 re-samples). The pattern of reliability across all effects was confirmed using pairwise *t*-tests with the Bonferroni multiple-comparisons correction.

The means for total sentence reading time are presented in Table 1. There were no reliable differences between normal and PM font across any of the four conditions [all p_{rep}<.70, abs(d)<.40, p(strong support)<.50]. Other indices of general processing difficulty – reading time per character, average fixation duration, and number of fixations per sentence – showed the same (non-significant) pattern.

Insert Table 1 about here

The means for saccade length in pixels are presented in Table 2. Pixel measurement represents absolute distance. Saccade length (pixels) was reliably longer for PM versus normal text across all conditions (parafoveal text was larger in PM conditions). Saccades were shortest in the 7-character window condition, both for normal and PM font. Within normal and PM font conditions, there were no differences in saccade length between the no-window, 21- and 14-character window conditions [all $p_{rep}<.60$, abs(d)<.06, p(strong support)<.50].

Insert Table 2 about here

Saccade length was also calculated in terms of number of characters, representing a text-based measurement. Means for saccade length in characters are presented in Table 3. In contrast to the pixel results, no differences were found between normal and PM font in terms of character distance [all $p_{rep}<.80$ and abs(d)<.75, p(strong support)<.50], except in the 7-character condition [$p_{rep}=.82$ and abs(d)=.88; however, p(strong support) was only .53]. As before, saccades were shortest in the 7-character window condition, both for normal and PM font. Again, there was no reliable difference in saccade length between the no-window, 21- and 14-character window conditions [all $p_{rep}<.60$ and abs(d)<.15, p(strong support)<.50]. The apparent paradox – significantly longer pixel saccades but numerically (non-significantly) shorter character saccades with PM versus normal font – may be explained by the fact that saccadic undershoots are more probable with greater eccentricities. With PM font, the saccade target is physically much further away than with normal font.

Insert Table 3 about here

Finally, we compared saccade length in characters for each participant reading normal versus PM font. Although average saccade length varied between participants (e.g., between 6 and 12 characters with normal font), it remained remarkably constant across font within individual participants [r(38)=.80, p_{rep}>.99].

Experiment 2

We examined reading time measures on the adjective (Word1, the first word of the NP) for evidence of parafoveal-on-foveal processing – whether properties of the parafoveal noun (Word2, the second word of the NP) affected fixation time on Word1. Specifically, we examined first fixation duration (FFD; the duration of the first instance a word is fixated), single fixation duration (SFD; the duration of first-and-only fixations; the majority of cases), and gaze duration (GD; the summed duration of successive fixations before leaving a word).

We used a repeated-measures multiple regression analysis (Lorch & Myers, 1990) for each fixation time measure. Such analyses avoid using dichotomized variables (e.g., HF, LF) when actual values are available, and the variance explained by a set of predictors with known values can be removed from the error variance. This allowed us to assess the relative weight of Word2's characteristics on Word1's fixation time, independent of the influence of other predictors.

For all analyses, the regressors were psycholinguistic and oculomotor characteristics of Word1 and Word2: word length; natural log frequency; predictability, plausibility of the NP; launch distance to the beginning of Word1; total saccade length to Word1; location of the first fixation on Word1 (i.e., the number of letters before the end of Word1). All interactions with fixation location on Word1 were also included, as this directly influences the degree to which Word2 can be processed parafoveally. R^2, F, p_{rep}, and beta values for statistically reliable predictors are given in Tables 4 and 5 for SFD (mean=257 ms) and GD (mean=295 ms), respectively. As in Experiment 1, our criterion for reliability was p_{rep}>.80 (confirmed with standard *p*s<0.05). FFD showed a pattern of results similar to SFD.

Insert Tables 4-5 about here

On early measures of Word1, only lower-level characteristics of Word2 significantly influenced Word1: in both FFD and SFD, there was an effect of Word2 length and an interaction between Word1 fixation location and Word2 length. A main effect of Word2 length also emerged in GD. In general, an upcoming word's length has not been reported to affect fixation time on the current word. However, Kliegl, Nuthmann, and Engbert (2006) did show such an effect, but only in GD. Moreover, Miellet et al. (2007), who presented the materials from Experiment 2 in normal font, also reported a similar effect in GD [F=4.46, p<.01], but not in FFD or SFD [all *F*s<1]. In the present study, the PM paradigm accentuates and augments parafoveal word length. It is possible that the effect on Word1 of Word2's length reflects an aspect of programming saccades to longer words in an unfamiliar reading environment. A recent study showed shorter saccadic latencies when attention is directed to a smaller object (Harwood, Madelain, Krauzlis, & Wallman, 2008). Because PM exaggerates the difference between short and long words, this alone could lead to parafoveal-on-foveal effects of word length.

Higher-level, lexical parafoveal-on-foveal effects only appeared in the later GD measure: there were interactions between Word1 fixation location and Word2's frequency and predictability. Miellet et al. (2007), using normal font and the same materials, did not find any evidence of parafoveal-on-foveal effects of frequency or predictability in FFD, SFD, or GD [all *F*s<1].

Discussion

In summary, our study demonstrated that the perceptual span in reading is mainly governed by attentional demands and not by acuity limitations. We additionally tested parafoveal-on-foveal processing, a topic which is critical to competing models of eye movement control. Our results favor SAS models of eye guidance. To explore these issues, we introduced a new method of reading – PM – allowing us to tease apart the relative contributions of visual acuity and attention. We showed that, although the physical appearance of PM text is highly non-standard, reading proceeds quite normally.

In Experiment 1, although PM induced physically longer pixel saccades than normal text, character saccade length was similar across font. This demonstrates that the perceptual span is delineated in terms of amount of information rather than a physical metric. This replicates Morrison and Rayner (1981) and extends their findings in a paradigm which compensates for acuity drop-off.

Reading behavior, however, was affected by the size of the moving window. Saccades were shortest with a 7-character window, both in normal and PM font. Moreover, saccade length was identical for the 14- and 21-character and no-window conditions. This replicates the classic finding of a 14-character perceptual span to the right of fixation for normal text (McConkie & Rayner, 1975), and extends it to the PM context. These results confirm that the perceptual span is limited by attentional rather than visual constraints, with the physical size of the span adapting to the amount of information to process.

We also found that, while saccade length varied between participants, a given individual's saccade length (in characters) was relatively stable across normal and PM font. The fact that this behavior occurred with PM after only 5 practice sentences indicates that individuals were able to immediately adapt their saccadic programs to drastically different display types.

Experiment 2 showed effects of frequency and predictability of the noun (Word2) on fixations on the adjective (Word1). These effects did not occur in early measures, but in GD. Moreover, they appeared only as interactions with the location of the first fixation on Word1, and the global variance explained was quite small. Proponents of attentional gradient (GAG) models of eye movement control would interpret these effects as evidence for parallel processing of several words. Proponents of serial (SAS) models, however, have recently suggested that parafoveal-on-foveal effects arise from fixations which are the result of saccadic undershoots of the parafoveal word, landing instead on the foveal word (Rayner, Warren, Juhasz, & Liversedge, 2004; Drieghe, Rayner, & Pollatsek, 2008), although this claim has been challenged by Kennedy (in press). As our effects were observed only when there were multiple fixations on Word1 and in interaction with the location of the first fixation on Word1, the overall pattern of results in Experiment 2 lends support to SAS models with parafoveal-on-foveal effects driven by saccadic undershoots.

According to the "undershoot" hypothesis, parafoveal-on-foveal effects should appear on the final fixation (of multiple fixations, in the case of GD) on Word1, but only when this fixation is close to Word2. Unfortunately, we could not test this hypothesis because there were too few cases of two successive fixations on Word1 in our dataset (only 246 data points). A parallel model would also predict greater parafoveal-on-foveal effects for fixations near the end of a word because the next word is more visible. However, acuity did not decline in our experiment. Acuity drop-off was a factor in Miellet et al. (2007) where participants read the materials from Experiment 2 in a normal font. Their analyses only revealed a parafoveal-on-foveal effect in GD on Word1 of Word2's length, but not its frequency or predictability. With PM, it seems that the very same mechanism that facilitates parafoveal processing (increased text size) also generates more saccadic undershoots because the parafoveal target is further away.

From this research, several directions can be pursued. The first concerns a stronger test of parafoveal semantic pre-processing. One limitation of Experiment 2 was that, although the *plausibility* of the noun phrase was carefully manipulated, the lexical *predictability* of the noun (as assessed by the Cloze task) was fairly weak. If the nouns were contextually highly predictable, reliable early fixation time parafoveal-on-foveal effects might be observed on the adjective.

A more fundamental issue concerns the act of reading itself. All our participants had nearly two decades of experience reading text in normal font – their PM experience was limited to 100 or so sentences (including practice). Thus, perceptual learning may play a significant role (e.g., Nazir et al., 1998). In terms of global measures of reading, PM neither helped nor hurt reading performance. This most likely arose from two opposing influences of PM: (1) a facilitative effect due to easier identification of parafoveal letters, and (2) a disruptive effect due to processing spatially atypical parafoveal information. Bai, Yan, Zang, Liversedge, and Rayner (in press) developed a similar argument to explain why non-standard, spaced presentation of words in Chinese neither aids nor impairs reading. In a context contrived to maximize the perceptual impact of text, several hours of PM training may indeed prove beneficial to reading behavior.

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Table 1

Average Sentence Reading Time (in Seconds) in Normal and PM Font Conditions in Experiment 1

	Reading Time (sec)	
Condition	Normal	PM
no window	2.00	2.08
21	1.95	2.11
14	1.96	2.05
7	2.14	2.13

Note: Window conditions of 21, 14, and 7 refer to the number of valid rightward characters displayed.

Table 2

Average Saccade Length (in Pixels) and Reliable Comparisons in Normal and PM Font Conditions in Experiment 1 with Corresponding p_{rep} and Effect Size (d) Values

	Saccade Length (pixels)		Normal vs. PM	
Condition	Normal	PM	p_{rep}	abs(d)
no window	79	90	0.79	0.95
21	78	89	0.95	1.08
14	78	90	0.97	1.11
7	67	73	0.81	0.76

	Normal		PM	
Comparison	p_{rep}	abs(d)	p_{rep}	abs(d)
7 vs. no window	0.90	1.00	0.95	1.30
7 vs. 21	0.90	1.05	0.92	1.16
7 vs. 14	0.98	1.43	0.95	1.35

Note: Window conditions of 21, 14, and 7 refer to the number of valid rightward characters displayed.

Table 3

Average Saccade Length (in Characters) and Reliable Comparisons in Normal and PM Font Conditions in Experiment 1 with Corresponding p_{rep} and Effect Size (d) Values

Condition	Saccade Length (characters): Normal	Saccade Length (characters): PM
no window	8.26	7.63
21	8.22	7.58
14	8.25	7.66
7	7.16	6.56

Comparison	Normal p_{rep}	Normal abs(d)	PM p_{rep}	PM abs(d)
7 vs. no window	0.87	0.98	0.92	1.39
7 vs. 21	0.91	0.99	0.95	1.27
7 vs. 14	0.97	1.38	0.95	1.51

Note: Window conditions of 21, 14, and 7 refer to the number of valid rightward characters displayed.

Table 4

R^2, *F*, p_{rep}, and beta Values for Each Predictor for Single Fixation Duration (SFD) in Experiment 2

Predictor	R^2	*F*	p_{rep}	beta
ln frequency 1	0.0294	34.84	1.00	-0.0077
word length 2	0.0051	6.07	0.99	-0.0059
launch distance 1	0.0048	5.73	0.98	0.0046
fixation location 1	0.0033	3.92	0.96	-0.0131
saccade length 1	0.0029	3.42	0.95	0.0058
word length 1	0.0021	2.52	0.91	0.0028
word length 2 * fixation location 1	0.0020	2.36	0.90	0.0011

Note: Data are sorted according to p_{rep} values. Variables ending in "1" refer to aspects of Word1 (the adjective); those ending in "2" refer to aspects of Word2 (the noun).

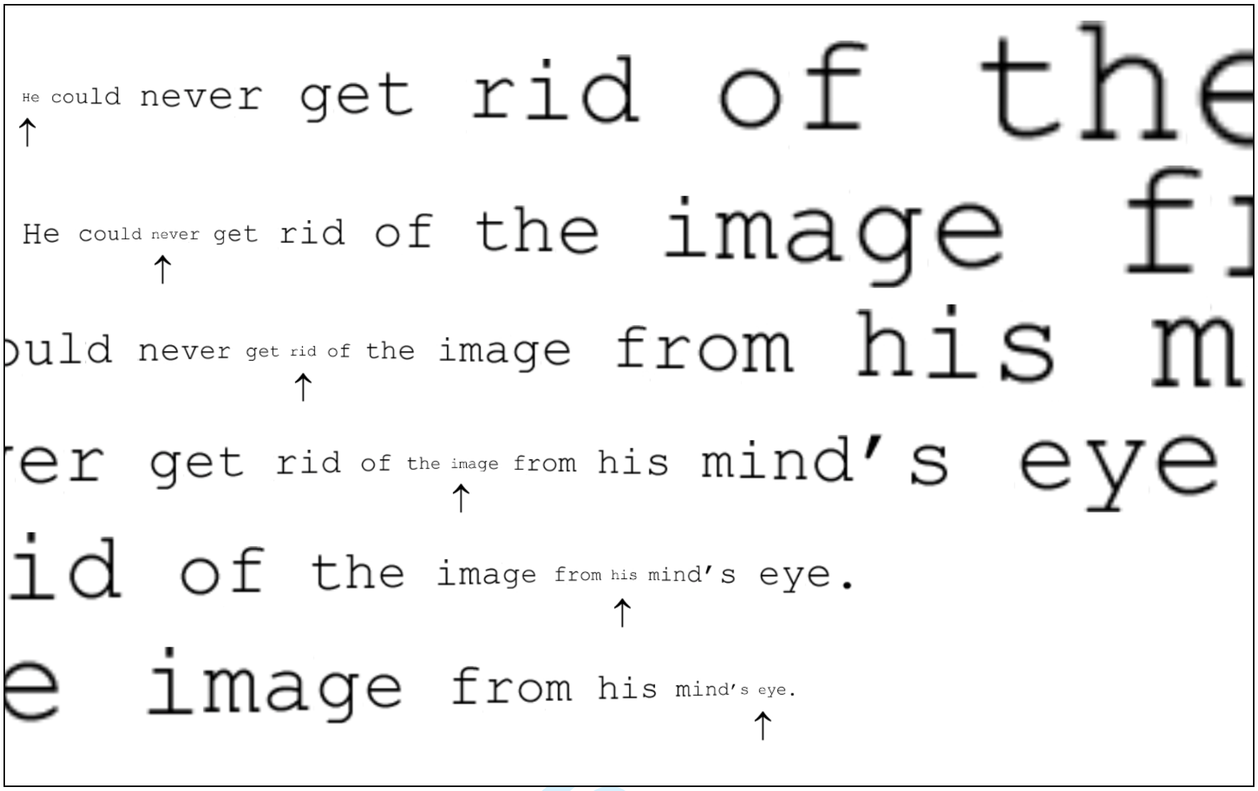
Table 5

R^2, F, p_{rep}, and beta Values for Each Predictor for Gaze Duration (GD) in Experiment 2

Predictor	R^2	F	p_{rep}	beta
ln frequency 1	0.0279	45.90	1.00	-0.0116
launch distance 1	0.0041	6.72	0.99	0.0063
word length 1	0.0026	4.20	0.97	0.0026
saccade length 1	0.0024	3.99	0.96	0.0061
ln frequency 2 * fixation location 1	0.0021	3.38	0.95	-0.0013
predictability 2 * fixation location 1	0.0019	3.06	0.94	-0.0193
fixation location 1	0.0017	2.74	0.92	0.0061
predictability 1	0.0013	2.14	0.88	0.1618
word length 2	0.0010	1.66	0.82	-0.0040

Note: Data are sorted according to p_{rep} values. Variables ending in "1" refer to aspects of Word1 (the adjective); those ending in "2" refer to aspects of Word2 (the noun).

Figure 1. Graphical depiction of the parafoveal magnification (PM) paradigm. The location of each fixation is indicated with an arrow and the corresponding display for that fixation is represented. Consecutive lines represent the chronological order of fixations.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