frontiers
in Psychology

When the eyes no longer lead: Familiarity and length effects on Eye-Voice Span

Susana Silva[1, 2*], Alexandra Reis[2], Luís Casaca[2], Karl Magnus Petersson[3, 4, 2], Luís Faísca[2]

[1]Center for Psychology at the University of Porto, University of Porto, Portugal, [2]CBMR, University of Algarve, Portugal, [3]Neurobiology of Language, Max Planck Institute for Psycholinguistics, Netherlands, [4]Language in interaction, Donders Institute for Brain, Cognition and Behaviour, Netherlands

Submitted to Journal:
Frontiers in Psychology

Specialty Section:
Language Sciences

ISSN:
1664-1078

Article type:
Original Research Article

Received on:
16 Jan 2016

Accepted on:
18 Oct 2016

Provisional PDF published on:
18 Oct 2016

Frontiers website link:
www.frontiersin.org

Citation:
Silva S, Reis A, Casaca L, Petersson K and Faísca L(2016) When the eyes no longer lead: Familiarity and length effects on Eye-Voice Span. *Front. Psychol.* 7:1720. doi:10.3389/fpsyg.2016.01720

When the Eyes No Longer Lead: Familiarity and Length Effects on Eye-Voice Span

Susana Silva1,2*, Alexandra Reis2, Luís Casaca2, Karl Magnus Petersson2,3,4, Luís Faísca2

[1] Center for Psychology at the University of Porto (CPUP), University of Porto, Portugal

[2] Centre for Biomedical Research (CBMR), University of Algarve, Portugal

[3] Max Planck Institute for Psycholinguistics, The Netherlands

[4] Donders Institute for Brain, Cognition and Behaviour, The Netherlands

*** Correspondence:** Susana Silva, Neurocognition and Language Research Group, Center for Psychology at the University of Porto, Faculty of Psychology and Educational Sciences, University of Porto, Rua Alfredo Allen, 4200-135, Porto, Portugal, zanasilva@gmail.com

Keywords: Eye-voice span, Eye-tracking, Reading aloud, Dual-route, Sublexical processing

Word count (body text): 5735

Abstract

During oral reading, the eyes tend to be ahead of the voice (eye-voice span). It has been hypothesized that the extent to which this happens depends on the automaticity of reading processes, namely on the speed of print-to-sound conversion. We tested whether EVS is affected by another automaticity component - immunity from interference. To that end, we manipulated word familiarity (high-frequency, low-frequency and pseudowords) and word length as proxies of immunity from interference, and we used linear mixed effects models to measure the effects of both variables on the time interval at which readers do parallel processing by gazing at word N+1 while not having articulated word N yet (offset eye-voice span). Parallel processing was enhanced by automaticity, as shown by familiarity x length interactions on offset eye-voice span, and it was impeded by lack of automaticity, as shown by the transformation of offset eye-voice span into voice-eye span (voice ahead of the offset of the eyes) in pseudowords. The relation between parallel processing and automaticity was strengthened by the fact that offset eye-voice span predicted reading velocity. Our findings contribute to understand how the offset eye-voice span, an index that is obtained in oral reading, may tap into different components of automaticity that underlie reading ability, oral or silent. In addition, we compared the duration of the offset eye-voice span with the average reference duration of stages in word production, and we saw that the offset eye-voice span may accommodate for more than the articulatory programming stage of word N.

Introduction

When readers name multiple items, the eye is usually ahead of the voice. This is known as eye-voice span (Inhoff et al., 2011; Laubrock & Kliegl, 2015; Pan et al., 2013) or eye-voice lead (De Luca et al., 2013). Eye-Voice Span (EVS) can be defined either in terms of space (the distance between the currently articulated item and the currently fixated one, *spatial EVS*), or in terms of time (how long it takes to articulate the item after having fixated it, *temporal EVS*). When EVS is defined in terms of time (Figure 1), a distinction is made between the time from the *onset of word fixation* to the onset of word naming (*onset EVS*), and the time from the *offset of word fixation* to the onset of word naming (*offset EVS*). The temporal onset EVS of word N is equivalent to the naming latency for that word. It encompasses all stages of word processing that take place before articulation, and may thus be referred to as the word's processing time (Figure 1). The temporal offset EVS of word N refers to a shorter period. During this period, the reader gazes at word N+1 while not yet having started to articulate N (Figure 1A). The temporal offset EVS is a particularly interesting period, in that it seems to signal the reader's engagement in the parallel processing of N and N+1, and thus some of her/his reading skills. Offset EVS is the focus of the present study, where we investigate the extent to which it depends on one of the components of automaticity - immunity to interference (Cohen et al., 1992; Moors, 2016; Moors & De Houwer, 2006).

Attention to EVS has resurged in the current decade, after a hiatus of nearly a century (see Buswell, 1921; Fairbanks, 1937). A major research goal has been to determine whether and how the length of EVS affects eye movements, and there has been agreement on the finding that eye movements on a word may be adjusted (the eyes may "wait for the voice") for the sake of keeping a more or less constant EVS across the text (Inhoff et al., 2011; Laubrock & Kliegl, 2015). Since current models of eye movements in reading such as SWIFT (Engbert et al., 2005) and EZ-reader (Reichle et al., 2003) have been designed for silent reading, determining the influence of the eye-voice dynamics on eye movements is a means to expand these models to oral reading. A different and less emphasized research goal has focused on the reverse question, that is, what determines EVS itself. This is what we are concerned with in the present study, where we seek to better understand the meaning of the temporal offset EVS.

Why do readers gaze at a new word without having articulated the previous word? An available explanation for EVS is that the eyes tend to be ahead of the articulatory system because visual processing is faster than articulation (Laubrock & Kliegl, 2015). Although plausible, this approach seems insufficient once the influence of EVS on eye movements is considered: if the eyes can wait for the voice (Inhoff et al., 2011; Laubrock & Kliegl, 2015), why do the eyes go ahead? Specifically, why does the reader start gazing at word N+1 before articulating N (offset EVS), if s/he seems able to delay the eyes and keep them on word N? The simplest answer seems to be that the lag between eyes and voice is useful. If the reader uses the initial gaze time on N+1 to finish the processing of N (Jones et al., 2008; 2016; Laubrock & Kliegl, 2015; Protopapas et al., 2013) and does *parallel processing* of the two items, s/he saves time. If the eyes waited for articulation onset in order to move forward to the next word, the process would be less efficient. Of course, one may also admit that the reader already completed the processing of word N by the time he/she starts gazing at N+1, in which case there would be no parallel processing. However, it is hard to explain why the reader would delay the articulation of N in that case. So, there seems to be no better explanation for the offset EVS period than the fact that parallel processing is unfolding, and the most likely scenario is that the reader is decoding item N+1 at the same time that s/he plans the articulation of N (the last processing stage before articulation).

The notion that parallel processing takes place during offset EVS is not too controversial, but several questions remain unanswered. The first question concerns the cognitive constraints on parallel processing and, hence, on offset EVS. It has been suggested that the presence of an offset EVS period benefits from *automaticity* in reading (e.g., Laubrock & Kliegl, 2015). Automaticity is commonly approached as a multi-componential construct, in that it is defined by the combination of several features, or components (Cohen et al., 1992; Moors, 2016; Moors & De Houwer, 2006). Two of these components are processing speed (more automatic processes are faster; see Cohen et al., 1992; Moors, 2016; Moors & De Houwer, 2006) and release from attentional control, which in turn affords immunity from competing processes, or *immunity from interference* (Cohen et al., 1992). The relation between automaticity and EVS has been supported by findings that dyslexic subjects, who lack automaticity, show decreased EVS values compared to controls (De Luca et al., 2013), and the same goes for autistic subjects (Hogan-Brown et al., 2014). The idea that EVS reflects automaticity is also supported by findings that EVS predicts naming velocity for automatized processes such as digit naming, but not for less automatized processes such as dice naming (Pan et al., 2013). In these studies, the link between automaticity and EVS has been framed around the processing speed component of automaticity (Hogan-Brown et al., 2014; Laubrock & Kliegl, 2015; Pan et al., 2013): it has been argued that the speed (automaticity) of print-to-sound conversion is key to EVS. The potential role of the other automaticity component, immunity from interference, on EVS has remained unexplored. Nevertheless, immunity from interference is expected to facilitate the parallel processing of two adjacent words. If the processing of word N+1, word N, or both, consumes few attentional resources, the processing of one word is immune to the competition of the other word, and the processing of several words may overlap in time (Protopapas et al., 2013), as it seems to occur during the offset EVS period. In order to examine how immunity from interference affects offset EVS, we used word familiarity as a proxy of this automaticity component.

The familiarity of a word is known to determine the relative activation of two different processes or routes, lexical and sublexical (Coltheart, 2006; Coltheart et al., 2001; Perry et al., 2007; Perry et al., 2010; Perry et al., 2013, Zorzi, 2010). High-frequency words (highly familiar) are expected to activate the lexical route more than low-frequency (less familiar) ones and pseudowords (totally unfamiliar), and pseudowords are expected to activate the sublexical route more than low- and high-frequency words. Critically, the lexical route is known to be more automatic than the sublexical one, in the specific sense that it is immune to increases in memory load, while the sublexical route is not (Paap & Noel, 1991). Therefore, if immunity from interference determines offset EVS, we expect to see increased offset EVS values for high-frequency words compared to the other classes. As a high-frequency N+1 word would require less attentional control and would be more immune to interference than an N+1 pseudoword, simultaneous (parallel) processing of N and N+1 would be facilitated in the first case. Since lexical route processes are less dependent from word length than the grapheme-to-phoneme conversion processes of the sublexical route (Barton et al., 2014; Juphard et al., 2004; Rastle & Coltheart, 1998; Rastle & Coltheart, 1999; Weekes, 1997; Ziegler et al., 2001; Zoccolotti et al., 2005), we also test for frequency x length interactions on offset EVS and we expect that the offset EVS of low familiarity words show increased length effects than the offset EVS of low-familiarity ones. To our knowledge, word familiarity effects on EVS have only been investigated by Halm and colleagues (2011), who found frequency effects on spatial EVS but not on temporal EVS. Since this paper is a very brief one, and the authors do not specify whether they measured the onset EVS or the offset EVS, uncertainty remains.

A second question pertains the type of relation between automaticity (in the sense of release from attentional control, leading to immunity from interference) and offset EVS. Possible evidence that automaticity *favours* the parallel processing taking place during offset EVS, i.e., that familiarity *modulates* offset EVS, does not lead to the obligatory conclusion that automaticity *is necessary* to parallel processing. In theory, parallel processing does not necessarily imply automaticity, and two scenarios may illustrate this possibility. One, the processes unfolding in parallel may depend on different cognitive subsystems which do not require the same attentional resources (Cohen et al., 1992). Two, the processes could require the same attentional resources, but the amount required by both may not exceed the available capacity. In these two scenarios, quantitative modulations of offset EVS by familiarity (shorter or longer EVSs) may still occur for several reasons. However, if automaticity is necessary, and the parallel processing of words is based on processes outside attentional control, lack of automaticity should *eliminate the possibility* of parallel processing, hence of offset EVS itself. Therefore, we posed the following question: under extreme decreases of automaticity, does a strict offset *eye-voice* span disappear, such that the eye “no longer leads” and the articulation of N begins while the reader is still gazing at N? Do low-automaticity settings, such as pseudowords, cause the eyes to remain on the word after naming onset? This scenario is portrayed in Figure 1B. For convenience, we named it simply *voice-eye span*, even though the voice onset is not ahead of the eyes in a straightforward manner, that is, the voice onset is not ahead of fixation onset, but ahead of fixation offset. In order to know the extent to which voice-eye span emerges (and parallel processing vanishes), we analysed the distribution of offset EVS values for each familiarity x length condition, and we located the point at which offset EVS values become negative.

Whether automaticity is beneficial or necessary to offset EVS (and the possibility of parallel processing), offset EVS should predict reading velocity, since reading velocity itself depends on automaticity. A critical way of testing this would be examining whether the offset EVS of the experimental task predicts reading velocity in a concurrent task, since this would tap into readers’ automaticity skills in different contexts. Thus, in order to strengthen our analysis, we tested if offset EVS predicted reading velocity in the 3DM reading test (see methods).

Finally, the notion that parallel processing takes place during offset EVS raises a third question - the question of *which processing stages of N* take place while readers gaze at N+1. Two different perspectives are found in the literature. While Laubrock and Kliegl (2015) argued that word N enters the memory buffer (the offset EVS period) as a phonological form and parallel processing is restricted to motor (articulatory) planning, others (Jones et al., 2008, 2016) have claimed that previous processing stages of N, such as phonological processing, may develop during the offset EVS period. In order to shed some light on this, we explored the compatibility of the offset EVS in highly familiar words (highest EVS expected) with the estimated duration of the articulatory programming stage, which is around 150 ms (Indefrey, 2011). If we find offset EVS values considerably longer than 150 ms, this will suggest that processes other than motor planning (the last in the processing chain) may be part of the processing of N in parallel with N+1.

Our approach is novel in two ways. First, unlike recent studies on EVS for text (De Luca et al., 2013; Inhoff et al., 2011; Laubrock & Kliegl, 2015), we present single words in blocked lists (high-frequency, low-frequency and pseudowords in separate lists), rather than connected, sentence-like text. It is known that the combination of familiar and unfamiliar words (mixed lists) favors grapheme-to-phoneme conversion processes in familiar words (Lima & Castro, 2010) and thus decreases the familiarity-related contrast between lexical and sublexical processing. Since the effect of mixed lists is also expected in connected text, we used blocked lists to maximize such contrast and thus allow the emergence of extreme levels of automaticity (blocked high-frequency words) and lack of automaticity (blocked pseudowords).

Additionally, we explore a novel approach to offset EVS, involving an EVS-related measure that we named *Gaze Time to Processing Time ratio* (GT/PT, Figure 1). GT/PT is obtained by dividing the gaze time on a word by the onset EVS (the processing time) of the same word. One advantage of GT/PT is that it is suitable for describing eye-voice span (gaze time shorter than processing time, Figure 1A) as well as voice-eye span (gaze time longer than processing time, Figure 1B). A second advantage of GT/PT is that it is a relative measure, describing the weight of different processing stages (gaze-dependent vs. gaze-independent) within the onset EVS (naming latency) period. A relative measure such as this is crucial to validate offset EVS results, since it describes *the contribution* of parallel processing to the complete processing (naming latency) of a given word, rather than just the duration of the parallel processing stage (offset EVS). Offset EVS (absolute) values may be misleading in the sense that differences in offset EVS between words do not necessarily mean different contributions of parallel processing. For instance, offset EVS values of 300 ms and 600 ms indicate equivalent contributions of parallel processing if naming latencies (onset EVS, or processing time) are 600 ms and 1200 ms, respectively (contribution of 50% in both). Conversely, it is possible that the offset EVS values of two words differ little (e.g., 300 ms vs. 350 ms), but such differences reflect important contrasts in the contribution of buffer-based processing (e.g., for processing times of 600 ms vs. 400 ms, respectively). In order to control for possible misleading effects of offset EVS (absolute) values, we performed the analysis of familiarity x length effects on both measures, and we compared the effects of both measures on scores of reading velocity.

Insert Figure 1 about here, please

Material and methods

Participants

Forty subjects volunteered to take part in the experiment, but four were excluded due to excessive eye artefacts. Thus, thirty-six Portuguese native-speakers (21 female; Mean age ± *SD* = 26±5; Mean years of schooling ± *SD* = 15±2) were included in the analysis. All had normal or corrected-to-normal vision. None had neurological problems or was taking drugs. Screening tests (QHL, Castro & Alves, 2005; 3DM, Reis et al., 2014) showed no indications of reading disability. Participants signed informed consent, according to the declaration of Helsinki.

Stimuli

We selected 80 high-frequency (HF) and 80 low-frequency (LF) words from CLUL database (Bacelar do Nascimento et al., 2000), which provides absolute frequency values found in a corpus of 16 210 438 words (see Figure 2 to visualize log-transformed frequency values per class). We generated a set of 80 pseudowords (PW, see appendix). In each familiarity level, there were 40 short (4-5 letters; 30 regular and 10 irregular) and 40 long items (8-9 letters; 30 regular and 10 irregular). Short and long HF words did not differ in frequency (Means: short - 1339.90, long -1334.00), neither did LF words (short -12.30, long - 12.98). The six familiarity x length levels were balanced for bigram frequency (Means: HF- short 60549, HF - long 64635, LF - short 64777, LF - long 63291, PW - short 62290, PW - long 61416) and neighborhood density (Mean 0.6 in all). In total, there were 240 (80 x 3) experimental stimuli organized into 30 lists for multiple-item presentation (see Figure 2 for an example). The items in each list had the same level of familiarity, length and regularity status. Lists of long words or pseudowords comprised 12 items (3 rows x 4 columns), and lists of short words comprised 15 (3 rows x 5 columns). Filler items were included (filler words in word lists and filler pseudowords in pseudoword lists), so as to avoid artefacts at critical positions (first column and last word slot of each list), and also to keep the number of items constant across lists. There were 156 filler items, summing up to 396 (240+196) stimuli.

The 3DM test, which we used for screening reading disability (see Participants section), had a second purpose in our study: we also used it as a measure of individual reading velocity. We wanted to know whether offset EVS values for our experimental stimulus set could predict reading velocity in a concurrent test (see Statistical analysis section), so as to strengthen possible evidence that EVS taps into reading velocity (see Introduction). In the 3DM test, participants were presented with 75 low-frequency words, 75 high-frequency words and 75 pseudowords (none of these included in the eye-tracking experiment) for a fixed time interval. Their task was to name as many words or pseudowords as possible.

Procedure

Participants were instructed to name the items, in rows, as accurately and fast as possible, while remaining still and avoiding blinking. They were asked to press the space bar of the computer keyboard at the end of each list. The 30 lists were randomly presented across subjects.

Eye movements were monocularly recorded at 1250 Hz with a tower-mounted SMI hi-speed eye tracking system (www.smivision.com). Subjects placed their head on a chin rest and sat 80 cm away from the monitor. At this distance, the minimal inter-word spacing subtended 6.8º of the visual angle and was, thus, larger than parafoveal vision. Vocal responses were recorded with a Logitech webcam, synchronized with the eye-tracker as provided by SMI “Observation package” software. Subjects were first given practice trials. The recording session started with a thirteen-point calibration procedure, and tracking errors larger than 0.5º led to a new calibration.

Data pre-processing

Events were extracted with a high-speed algorithm, using a peak velocity threshold of 30º to identify saccades. Fixations shorter than 50 ms were rejected. Trials (lists) were visually inspected for artefacts, and those with more than 25% of signal loss were marked as contaminated trials. Subjects with more than 25% contaminated lists were excluded from the analysis (see participants section). Audio data were analyzed offline with Praat software (http://www.fon.hum.uva.nl/praat/). Naming responses were classified for articulation accuracy (correct vs. misarticulated). Eye data per item x subject was scanned for blinks, lack of eye entry in the AOI (skipped item), and accidental eye entries at the onset of the list. Misarticulated items, as well as those containing any type of eye artefact (blink, skip or accidental entry) were removed from the analysis. Since the EVS is often readjusted by means of regressions (Inhoff et al., 2011), we excluded the items with second-pass reading from the analysis in order to keep the EVS uncontaminated from influences other than familiarity and length. After excluding misarticulations, eye artefacts, second-pass viewed items and outliers, we were left with 6734 data points for analyzing offset EVS, and 6504 data points (out of 8880) for Gaze Time to Processing Time ratio (GT/PT). Differences in the number of data points between the two variables were due to the exclusion of a different number of outliers in each.

Rectangular Areas Of Interest (AOIs) were placed around each word/pseudoword (Figure 2) to compute first-pass gaze times and onset EVS per item x subject. *Onset EVS* was calculated as the interval between the first valid eye-entry on the item’s AOI and the naming (articulatory) onset. *Offset EVS* per item x subject was obtained by subtracting first-pass gaze time to onset EVS of item N. Positive offset EVS values indicate that the eyes are ahead of the voice (Figure 1A), and negative ones indicate the opposite (starting to name an item before the eyes move forward, see Figure 1B). Finally, *Gaze Time to Processing Time ratio* (GT/PT) values (first-pass gaze time / onset EVS) were obtained. Values larger than 1 follow positive offset EVSs (Figure 1A) and values smaller than 1 follow negative offset EVS values (Voice-Eye Span, Figure 1B). The distributions of offset EVS or

GT/PT showed no marked deviations from normality.

Insert Figure 2 about here, please

Statistical analysis

We looked into descriptive statistics of offset EVS and GT/PT to determine if and when negative offset EVS and GT/PT values smaller than 1 (voice-eye span) would emerge. The mean and standard deviation of offset EVS and GT/PT for each stimulus class allowed us to estimate whether one standard deviation away from a positive offset-EVS mean (eye-voice span) would show negative values. This was complemented with percentile analyses, which specified, for each stimulus class, the percentile at which eye-voice span turned into voice-eye span. Mean offset EVS and GT/PT values were also used to investigate whether offset EVS periods might accommodate for processing stages other than motor programming (150 ms).

We used R (R core team, 2013) and *lme*4 (Bates et al., 2015) to perform linear mixed effects analyses of the effects of frequency and length (fixed effects, with an interaction term) on offset EVS and GT/PT. As random effects, we had intercepts for subjects and items, but no by-subject or by-item random slopes. This was due to lack of convergence in random-slope models for our data, which seems to be in line with the attention that has been paid to the risk of overparametrization (Bates et al., 2015). P-values were obtained by likelihood ratio tests of the full model with the effect/interaction in question against the model without that effect/interaction. Simple familiarity and length effects were tested against the intercept-only model, and familiarity x length interactions were tested against the model with both familiarity and length as fixed factors. To allow for these comparisons, models were fitted using the ordinary Maximum Likelihood (ML) criterion. We also followed the principle that, with a large sample size, absolute *t* values larger than 2 indicate significant results at the 5% level (Baayen et al., 2008), and this principle was used to analyse frequency x length interactions (Tables 2-3).

We used similar procedures to test for offset EVS and GT/PT as predictors of reading velocity in the concurrent 3DM test. We modelled reading velocity with offset EVS or GT/PT as predictors, and compared the two models with the intercept-only model.

Results

Eye-Voice Span vs. Voice-Eye span

The mean values of offset EVS (Figure 3) for all items (*M*±*SD*: 148 ± 187 ms) indicated that the readers' eyes were, on average, fixating N+1 (mean first-pass gaze time was 494 ms) when starting to name N. However, descriptive statistics for the six familiarity x length levels (Table 1) indicated a negative mean value for long pseudowords. Also, for low-frequency long words and all pseudowords, negative offset EVSs started as soon as one standard deviation below the mean (e.g., for LF long, 81 – 174 is negative). GT/PT values (Figure 3) showed a similar picture, with a mean GT/PT > 1 for long pseudowords and GT/PTs > 1 starting one standard deviation above the mean in low-frequency words and all pseudowords.

Percentile-based analyses indicated that GT/PTs > 1, or voice-eye spans, corresponded to percentiles 87, 74, 77 in HF short, HF long, LF short, and to percentiles 51, 59, 15 in LF long, PW short and PW long, respectively.

Insert Table 1 about here, please

Length of offset EVS vs. length of motor programming stage

The average values of offset EVS for long and short high-frequency words (191 and 259 ms), as well as for short low-frequency words (210 ms, see Table 1), were large enough to accommodate for more than the average time of motor programming (150 ms).

Familiarity and length effects on offset EVS and VDPT

For both offset EVS and GT/PT the analysis of fixed factors (Tables 2-3) showed significant effects of familiarity, length, and a significant familiarity x length interaction, indicating that the effects of length increased as familiarity decreased. Concerning random factors, the variance arising from subjects was larger than from items in both cases.

Insert Table 2 about here, please

Insert Table 3 about here, please

Insert Figure 3 about here, please

Offset EVS and GT/PT as predictors of reading velocity in 3DM

Both offset EVS and GT/PT predicted reading velocity scores. Reading velocity in 3DM increased as offset EVS in the experimental task increased (χ^2 (1) = 8.11, p = .004, see Figure 4), and it increased as GT/PT increased (χ^2 (1) = 7.38, p = .006).

Insert Figure 4 about here, please

Discussion

Current approaches to the dynamics of eye and voice during oral reading suggest that the extent to which the eyes go ahead of the voice depends on the automaticity of the processes involved, automaticity referring to the speed of those processes. We have expanded the work on this hypothesis by focusing on a different component of automaticity – release from attentional control, leading to immunity from interference. This automaticity component is conceptually close to the parallel processing taking place during the offset eye-voice span period, and thus we investigated its role empirically, using word familiarity and its interactions with word length as proxies of immunity from interference. Our goal was threefold. First, we wanted to gather further evidence that automaticity leads to increased offset EVS values. Second, we wanted to determine if extreme decreases in automaticity eliminate parallel processing and transform eye-voice span into voice-eye span, so as to clarify if automaticity is necessary to offset EVS, rather than just beneficial. Third, we wanted to get preliminary information on whether the processing of word N in parallel with word N+1 is limited to motor programming or, on the contrary, if it encompasses previous stages in the processing chain. We addressed these goals by investigating the effects of word familiarity and length on offset EVS as well as on an EVS-related measure that we named gaze time to processing time ratio. (GT/PT).

Supporting our predictions, automaticity (immunity from interference) lengthened the parallel processing period corresponding to offset EVS. Less familiar words elicited shorter offset eye-voice span values (absolute measure) as well as stronger investment on gaze during word processing (longer GT/PT values – relative measure), compared to more familiar words. Due to the categorical approach we made, our analyses highlighted the effects of different *levels* of automaticity. From this viewpoint, we concluded that a pseudoword (less familiar) requires, on average, longer offset EVSs than a high-frequency word (more familiar). Nevertheless, gradient effects were also apparent: among high-frequency words, words with the highest frequency values seemed to elicit the longest offset EVSs (see Figure 3), so it is highly likely that a continuous approach would also show significant effects. The effects of word length on offset EVS and GT/PT increased as familiarity decreased, signaling the interaction we predicted.

More than just beneficial, automaticity seems to be necessary to the parallel processing occurring during the offset EVS period. As familiarity decreased and length increased, a true eye-voice span vanished, and the reader started to name word N while still viewing it. Our data included many instances of voice-eye span, most of these found in low-frequency words and pseudowords. In low-frequency long words, data points that were one standard deviation above the mean represented voice-eye spans instead of eye-voice spans, and, in long pseudowords, even mean values did the same.

Finally, what is going on with word N while the eyes are ahead? Our findings are consistent with the possibility that the processing of N in parallel with N+1 is not restricted to motor programming, the last stage before articulation. For high-frequency (short and long) words and short low-frequency words, we saw mean offset EVS values that accommodate for more than the average duration of articulatory programming, which is about 150 ms (Indefrey, 2011). For instance, according to our results, short high-frequency words seem to allow both the syllabification (idem) and the articulatory programming of N in parallel with visual decoding of N+1, that is, during the offset EVS period. From this viewpoint, the idea that a word must be phonologically coded by the time it ceases to be fixated in order to resist memory decay (Laubrock & Kliegl, 2015) does not seem to be supported, but we should be extremely cautious about this at least for two reasons. First, we are dealing with mere referential values; second, the fact that offset EVS exceeds the reference duration of motor programming does not necessarily mean that other processes are taking place, and the processing of N may be simply suspended for a fraction of the offset EVS period.

In the comparative analysis of offset EVS with GT/PT, both measures exhibited the expected familiarity x length interactive effects, and both predicted reading velocity in the expected direction (velocity increased with longer offset EVS and decreased with larger GT/PT). Therefore, our results for offset EVS seem valid enough. Although, in our case, offset EVS measures were not misleading since GT/PT indices did not change the picture, the concept of GT/PT expressed the observed negative offset EVS values (voice-eye span) in a simpler, less biased way. GT/PT values larger than 1 indicate that readers spend more time gazing at the word than the time needed to process it (begin its articulation). In contrast, the idea of a negative offset EVS is less transparent. Therefore, GT/PT seems to hold, at least, a conceptual advantage over offset EVS.

Our findings contributed to strengthen the link between offset EVS and the automaticity of reading, but the fact that we manipulated automaticity in an indirect manner, that is, using proxies (word familiarity and length), is one limitation. Direct manifestations of automatic processes may be captured with stroop tasks (see Jones et al., 2016 for an example), which could be used in further studies to verify the relation between these processes and offset EVS.

In addition, our paradigm comprised a number of options that may have had a significant impact on our results. First, we chose to use lists of unconnected words because we wanted to potentiate familiarity effects. Finding out whether a different picture emerges (e.g., no voice-eye span) when using sentence-like materials that discard block effects and elicit semantic and syntactic integration, should stand as a next step in research. Second, we tried to eliminate parafoveal processing (Schotter et al., 2011) by controlling the inter-word space. The parafoveal processing that takes place when gazing at N+1 (previewing N+2) stands as an additional processing channel, and thus it is possible that there are less available resources for parallel processing during offset EVS when parafoveal processing is allowed.

The main contribution of our study was to strengthen the relation between offset EVS and automaticity in reading. Although we focused on measures that pertain to oral reading (offset EVS, GT/PT), the results of our study ultimately support the understanding of offset EVS (or its relative counterpart, GT/PT) as an index of automaticity, which underlies both oral and silent reading. Establishing offset EVS or GT/PT as indices of automaticity is an important step in clinical and experimental applications of the double-deficit hypothesis on dyslexia (Norton & Wolf, 2012; Wolf & Bowers, 1999), which proposed a distinction between phonological deficits and naming speed deficits in dyslexia cases. Lack of automaticity is a key feature of the naming-speed dyslexia type, which has been tapped with rapid automatized naming (RAN) tasks. Naming times have been used as indices of RAN performance, hence of automaticity. If offset EVS measures reflect automaticity, it may be helpful to add them when classifying dyslexia types.

Specifically, our study highlighted the relation between offset EVS and automaticity *viewed as immunity to interference*. Our findings are consistent with increasing evidence that dyslexic individuals – who typically show shorter EVSs - have problems in dealing with multiple presented items such as in RAN tasks (Jones et al., 2013; Jones et al., 2009; Jones et al., 2008; Zoccolotti et al., 2013), and they are particularly consistent with the interpretation that this is due to difficulties in managing between-item competing processes (e.g., processing one item while naming the previous one, and while previewing the next).

We wanted to test the effects of immunity to interference on offset EVS, and we used word familiarity as a proxy of immunity to interference. We did that based on Paap and Noel's (1991) findings, which have not been consistently replicated (Pexma & Lupker, 1995). Therefore, there is the possibility that our assumption is incorrect, and that activating the lexical route by presenting high-frequency words does not necessarily increase immunity from interference. Even if that is the case and we have not manipulated automaticity in our study, we are still left with evidence that the activation of the lexical route increases offset EVS. On the one hand, this may have implications for dual-route-based reading measures. Namely, it may afford measuring the reader's reliance on the sublexical route using decreases in eye-voice span as an index. This would add to available behavioral (Crisp & Lambon Ralph, 2006) and eye-movement indices (e.g., Hawelka et al., 2010; Rau et al., 2014; Schattka et al., 2010). On the other hand, the fact that parallel processing is increased in the lexical route (longer EVS) raises new theoretical perspectives on dual-route approaches. It indicates that the lexical route affords a view-independent stage of word processing, while the sublexical route does not. If the reasons for this do not relate to different levels of automaticity in the two routes, they may, for instance, relate to increased levels of visual monitoring in the sublexical route, which, to our knowledge, is a new finding.

In our approach to the offset EVS, we put the emphasis on the extent to which it is a manifestation of parallel timelines of word processing, and many questions remain unanswered concerning these timelines. One question that is raised by our findings is why the eyes remain on the word during articulation in cases of voice-span, instead of moving on to the next word as soon as articulation begins. May articulation itself be dependent on gaze? For which purpose? Under which circumstances? We believe that this and other questions may strongly benefit from using methods of co-registration of eye-tracking and EEG in future research.

Acknowledgments and funding

We are grateful to Loide Carvalho for her help with data acquisition.

Funding: This work was funded by Fundação para a Ciência e a Tecnologia under grants PTDC/PSI-PCO/110734/2009, EXPL/MHC-PCN/0299/2013, PEst-OE/EQB/LA0023/2014, UID/BIM/04773/2013 CBMR 1334, UID/PSI/00050/2013 and PTDC/MHC-PCN/1175/2014.

References

Baayen, R. H., Davidson, D. J., & Bates, D. M. (2008). Mixed-effects modeling with crossed random effects for subjects and items. *Journal of Memory and Language* 59(4), 390–412. http://doi.org/10.1016/j.jml.2007.12.005

Bacelar do Nascimento, M. F., Pereira, L. A. S., & Saramago, J. (2000). Portuguese corpora at CLUL. In M. Gavrilidou, G. Carayannis, S. Markantonatou, S. Piperidis, & G. Steinhaouer (Eds.), *Second International Conference on Language Resources and Evaluation – Proceedings: Vol. 2* (pp. 1603-1607). Athens, Greece: European Language Resources Association.

Barton, J. J. S., Hanif, H. M., Eklinder Björnström, L., & Hills, C. (2014). The word-length effect in reading: A review. *Cognitive Neuropsychology* 31(5-6), 378–412. http://doi.org/10.1080/02643294.2014.895314

Bates, D., Kliegl, R., Vasishth, S., & Baayen, H. (2015). Parsimonious mixed models. *arXiv preprint arXiv:1506.04967*.

Bates, D., Maechler, M., Bolker, B., Walker, S., Christensen, R. H. B., Singmann, H., ... & Rcpp, L. (2015). Package ‘lme4’. URL: https://cran.r-project.org/web/packages/lme4/index.html

Buswell, T. G. (1921). The relationship between eye-perception and voice-response in reading. *Journal of Educational Psychology* 12(4), 217–227. http://doi.org/10.1037/h0070548

Castro, S. L., & Alves, R. A. (2005). Despistagem da dislexia em adultos através do Questionário de História de Leitura. *Iberpsicología: Revista Electrónica de La Federación Española de Asociaciones de Psicología* 10(8), 9–.

Cohen, J. D., Servan-Schreiber, D., & McClelland, J. L. (1992). A parallel distributed processing approach to automaticity. *The American Journal of Psychology*, *105*(2), 239–269. http://doi.org/10.2307/1423029

Coltheart, M. (2006). Dual route and connectionist models of reading: an overview. *London Review of Education* 4(1), 5–17. http://doi.org/10.1080/13603110600574322

Coltheart, M., Rastle, K., Perry, C., Langdon, R., & Ziegler, J. (2001). DRC: A dual route cascaded model of visual word recognition and reading aloud. *Psychological Review* 108(1), 204–256. http://doi.org/10.1037/0033-295X.108.1.204

Crisp, J., & Lambon Ralph, M. A. (2006). Unlocking the nature of the phonological–deep dyslexia continuum: the keys to reading aloud are in phonology and semantics. *Journal of Cognitive Neuroscience* 18(3), 348–362. http://doi.org/10.1162/jocn.2006.18.3.348

De Luca, M., Pontillo, M., Primativo, S., Spinelli, D., & Zoccolotti, P. (2013). The eye-voice lead during oral reading in developmental dyslexia. *Frontiers in Human Neuroscience* 7. http://doi.org/10.3389/fnhum.2013.00696

Engbert, R., Nuthmann, A., Richter, E. M., & Kliegl, R. (2005). SWIFT: A dynamical model of saccade generation during reading. *Psychological Review* 112(4), 777–813. http://doi.org/10.1037/0033-295X.112.4.777

Fairbanks, G. (1937). The relation between eye-movements and voice in the oral reading of good and poor silent readers. *Psychological Monographs* 48(3), 78–107. http://doi.org/10.1037/h0093394

Halm, K., Ablinger, I., Ullmann, A., Solomon, M. J., Radach, R., & Huber, W. (2011). What is the eye doing during reading aloud? Eye-voice span in acquired dyslexia. *Procedia-Social and Behavioral Sciences* 23, 244-245.

Hawelka, S., Gagl, B., & Wimmer, H. (2010). A dual-route perspective on eye movements of dyslexic readers. *Cognition* 115(3), 367–379. http://doi.org/10.1016/j.cognition.2009.11.004

Hogan-Brown, A. L., Hoedemaker, R. S., Gordon, P. C., & Losh, M. (2014). Eye-voice span during rapid automatized naming: evidence of reduced automaticity in individuals with autism spectrum disorder and their siblings. *Journal of neurodevelopmental disorders* 6(1), 33.

Indefrey, P. (2011). The spatial and temporal signatures of word production components: a critical update. *Frontiers in psychology* 2: 255. http://dx.doi.org/10.3389/fpsyg.2011.00255

Inhoff, A. W., Solomon, M., Radach, R., & Seymour, B. A. (2011). Temporal dynamics of the eye–voice span and eye movement control during oral reading. *Journal of Cognitive Psychology* 23(5), 543–558. http://doi.org/10.1080/20445911.2011.546782

Jones, M. W., Ashby, J., & Branigan, H. P. (2013). Dyslexia and fluency: Parafoveal and foveal influences on rapid automatized naming. *Journal of Experimental Psychology: Human Perception and Performance*, *39*(2), 554–567. http://doi.org/10.1037/a0029710

Jones, M. W., Branigan, H. P., & Kelly, M. L. (2009. Dyslexic and nondyslexic reading fluency: Rapid automatized naming and the importance of continuous lists. *Psychonomic Bulletin & Review*, *16*(3), 567–572. http://doi.org/10.3758/PBR.16.3.567

Jones, M. W., Obregón, M., Kelly, M. L., & Branigan, H. P. (2008). Elucidating the component processes involved in dyslexic and non-dyslexic reading fluency: An eye-tracking study. *Cognition* 109(3), 389-407. doi:10.1016/j.cognition.2008.10.005

Jones, M. W., Snowling, M. J., & Moll, K. (2016). What automaticity deficit? Activation of lexical information by readers with dyslexia in a rapid automatized naming Stroop-switch task. *Journal* *of Experimental Psychology: Learning, Memory, and Cognition*, *42*(3), 465–474. http://doi.org/10.1037/xlm0000186

Juphard, A., Carbonnel, S., & Valdois, S. (2004). Length effect in reading and lexical decision: evidence from skilled readers and a developmental dyslexic participant. *Brain and Cognition* 55(2), 332–340. http://doi.org/10.1016/j.bandc.2004.02.035

Laubrock, J., & Kliegl, R. (2015). The eye-voice span during reading aloud. *Frontiers in Psychology* 6. http://doi.org/10.3389/fpsyg.2015.01432

Lima, C. F., & Castro, S. L. (2010). Reading strategies in orthographies of intermediate depth are flexible: Modulation of length effects in Portuguese. *European Journal of Cognitive Psychology* 22(2), 190–215. http://doi.org/10.1080/09541440902750145

Moors, A. (2016). Automaticity: Componential, Causal, and Mechanistic Explanations. *Annual Review of Psychology*, *67*(1), 263–287. http://doi.org/10.1146/annurev-psych-122414-033550

Moors, A., & De Houwer, J. (2006). Automaticity: A Theoretical and Conceptual Analysis. *Psychological Bulletin*, *132*(2), 297–326. http://doi.org/10.1037/0033-2909.132.2.297

Paap, K. R., & Noel, R. W. (1991). Dual-route models of print to sound: Still a good horse race. *Psychological Research*, *53*(1), 13–24. http://doi.org/10.1007/BF00867328

Pan, J., Yan, M., Laubrock, J., Shu, H., & Kliegl, R. (2013). Eye–voice span during rapid automatized naming of digits and dice in Chinese normal and dyslexic children. *Developmental Science* 16(6), 967–979. http://doi.org/10.1111/desc.12075

Perry, C., Ziegler, J. C., & Zorzi, M. (2007). Nested incremental modeling in the development of computational theories: The CDP+ model of reading aloud. *Psychological Review* 114(2), 273–315. http://doi.org/10.1037/0033-295X.114.2.273

Perry, C., Ziegler, J. C., & Zorzi, M. (2010). Beyond single syllables: Large-scale modeling of reading aloud with the Connectionist Dual Process (CDP++) model. *Cognitive Psychology* 61(2), 106–151. http://doi.org/10.1016/j.cogpsych.2010.04.001

Perry, C., Ziegler, J. C., & Zorzi, M. (2013). A computational and empirical investigation of graphemes in reading. *Cognitive Science* 37(5), 800–828. http://doi.org/10.1111/cogs.12030

Pexma, P. M., & Lupker, S. J. (1995). Effects of memory load in a word-naming task: Five failures to replicate. *Memory & Cognition*, *23*(5), 581–595. http://doi.org/10.3758/BF03197260

Protopapas, A., Altani, A., & Georgiou, G. K. (2013). Development of serial processing in reading and rapid naming. *Journal of Experimental Child Psychology*, *116*(4), 914–929. http://doi.org/10.1016/j.jecp.2013.08.004

R Core Team (2013). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. ISBN 3-900051-07-0, URL: http://www.R-project.org/.

Rastle, K., & Coltheart, M. (1998). Whammies and double whammies: The effect of length on nonword reading. *Psychonomic Bulletin & Review* 5(2), 277–282. http://doi.org/10.3758/BF03212951

Rastle, K., & Coltheart, M. (1999). Serial and strategic effects in reading aloud. *Journal of Experimental Psychology: Human Perception and Performance* 25(2), 482–503. http://doi.org/10.1037/0096-1523.25.2.482

Rau, A. K., Moeller, K., & Landerl, K. (2014). The transition from sublexical to lexical processing in a consistent orthography: an eye-tracking study. *Scientific Studies of Reading* 18(3), 224–233. http://doi.org/10.1080/10888438.2013.857673

Reichle, E. D., Rayner, K., & Pollatsek, A. (2003). The E-Z Reader model of eye-movement control in reading: Comparisons to other models. *Behavioral and Brain Sciences* 26(04), 445–476. http://doi.org/10.1017/S0140525X03000104

Reis, A., Faísca, L., Castro, S., Inácio, F., Pacheco, A., Araújo, S., & Santos, M. (2014). Versão Portuguesa da Bateria 3DM para avaliação da leitura e da escrita [3DM Portuguese version to assess reading and spelling skills]. *Manuscript in preparation*.

Schattka, K. I., Radach, R., & Huber, W. (2010). Eye movement correlates of acquired central dyslexia. *Neuropsychologia* 48(10), 2959–2973. http://doi.org/10.1016/j.neuropsychologia.2010.06.005

Schotter, E. R., Angele, B., & Rayner, K. (2011). Parafoveal processing in reading. *Attention, Perception, & Psychophysics*, *74*(1), 5–35. http://doi.org/10.3758/s13414-011-0219-2

Weekes, B. S. (1997). Differential effects of number of letters on word and nonword naming latency. *The Quarterly Journal of Experimental Psychology Section A* 50(2), 439–456. http://doi.org/10.1080/713755710

Ziegler, J. C., Perry, C., Jacobs, A. M., & Braun, M. (2001). Identical words are read differently in different languages. *Psychological Science* 12(5), 379–384.

Zoccolotti, P., De Luca, M., Di Pace, E., Gasperini, F., Judica, A., & Spinelli, D. (2005). Word length effect in early reading and in developmental dyslexia. *Brain and Language* 93(3), 369–373. http://doi.org/10.1016/j.bandl.2004.10.010

Zoccolotti, P., Luca, M. D., Lami, L., Pizzoli, C., Pontillo, M., & Spinelli, D. (2013). Multiple stimulus presentation yields larger deficits in children with developmental dyslexia: A study with reading and RAN-type tasks. *Child Neuropsychology*, *19*(6), 639–647. http://doi.org/10.1080/09297049.2012.718325

Zorzi, M. (2010). The connectionist dual process (CDP) approach to modelling reading aloud. *European Journal of Cognitive Psychology* 22(5), 836–860. http://doi.org/10.1080/09541440903435621

Tables

Table 1. Means (standard deviation) for offset EVS and GT/PT

	HF		LF		PW	
	Short	Long	Short	Long*	Short*	Long*
Offset EVS (ms)	258.9 (134.8)	191.4 (155.9)	210.2 (151.7)	80.9 (173.8)	122.7 (169.2)	-63.1 (185)
GT/PT (First-pass/onset EVS)	0.59 (0.18)	0.71 (0.23)	0.68 (0.22)	0.89 (0.28)	0.82 (0.27)	1.15 (0.36)

(*) Voice-Eye Span starting as soon as one standard deviation away from the mean

Table 2. Predictors of Offset EVS

Fixed effects	**Estimate**	**SE**	**T**	**Significance**
Familiarity				$\chi^{2(2)}=137.6$, $p <.001$
LF-HF	-80.77	14.91 -	-5.42*	
PW-HF	-202.20	15.00 -	-13.48*	
Length (Short-Long)	134.80	13.76	9.80*	$\chi^{2(1)}=81.1$, $p <.001$
Familiarity*Length				$\chi^{2(2)}=42.2$, $p <.001$
LF(Short-Long) – HF (Short-Long)	66.00	19.01	3.47*	
PW(Short-Long) – HF (Short-Long)	130.53	19.27	6.77*	
Random effects		**Variance**	**SD**	
Item	Intercept	8323.00	91.23	
Subject	Intercept	6093.00	78.05	
Residuals		16684.00	129.17	

Number of observations: 6734; Items: 240; Subjects: 36

Table 3. Predictors of Gaze Time / Processing Time

Fixed effects	**Estimate**	**SE**	**T**	**Significance**
Familiarity				$\chi^{2(2)}=147.2$, $p<.001$
LF-HF	0.18608	0.02049	9.079*	
PW-HF	0.44857	0.02132	21.038*	
Length (Short-Long)	-0.22579	0.02253	-10.02*	$\chi^{2\,(1)}=84.5$, $p<.001$
Familiarity*Length				$\chi^{2(2)}=44.3$, $p<.001$
LF(Short-Long) – HF (Short-Long)	-0.09339	0.02884	-3.24*	
PW(Short-Long) – HF (Short-Long)	-0.20501	0.02948	-6.95*	
Random effects		**Variance**	**SD**	
Item	Intercept	0.00679	0.08242	
Subject	Intercept	0.01295	0.11382	
Residuals		0.04395	0.20965	

Number of observations: 6504; Items: 240; Subjects: 36

Figure legends

Figure 1: Eye-Voice measures under two possible circumstances: (A) naming of N occurs while the reader views N+1 (Eye-Voice Span) and (B) Naming of N occurs while the reader is still viewing N (Voice-Eye Span). See text for more details (GT/PT = Gaze Time / Processing Time).

Figure 2: Example list (long pseudowords). Participants read the items in lines, as indicated by the example scanpath. Items in the first column, as well as the last item ("champalho") did not enter the analysis. Rectangles around each item indicate the AOIs, which were not visible during the experiment.

Figure 3: Offset EVS (left) and Gaze Time / Processing Time (right) as a function of familiarity (*HF* High-frequency, *LF* Low frequency, *PW* Pseudowords) and length (long vs. short). Offset EVS values < 0 indicate Voice-Eye Span instead of Eye-Voice Span, and so do Gaze Time/Processing Time (GT/PT) >1. Frequency values were log-transformed.

Figure 4: Reading velocity (measured by 3DM, maximum 75 words) as a function of Offset EVS (left) and GT/PT (right). Subject means are plotted.

Supplementary Material

Appendix - stimuli

High Frequency (HF)		Low Frequency (LF)		Pseudoword (PW)	
SHORT	LONG	SHORT	LONG	SHORT	LONG
café	negativo	acne	taxativo	madé	tamarela
bebé	medicina	bidé	tagarela	umpo	cexarevo
júri	rigoroso	bule	carapuço	jule	jigoroso
táxi	cerâmica	caju	vocativo	esbo	vobativo
base	pesquisa	guru	cernelha	tafe	pesmilha
tabu	permitir	maná	masmorra	jufe	masquisa
maré	resposta	osga	campista	xevo	pesmotir
rede	encontro	orbe	propalar	guse	blascemo
nulo	proposta	tule	madrigal	réxa	profemir

High Frequency (HF)		Low Frequency (LF)		Pseudoword (PW)	
bife	flexível	unto	blasfemo	xuna	maprigal
couve	habitação	pónei	carapinha	reipe	surailode
museu	revolução	naipe	bagaceira	naino	balicanha
peixe	narrativa	bouça	fuzileiro	reiça	reguvação
gesso	vacinação	rojão	serradura	beite	cabeleida
cupão	cabeceira	gibão	barricada	faute	sarrivada
beijo	televisão	quedo	pegureiro	mubão	balaceira
reino	sucessivo	sifão	saraivada	gipão	capoceiro
roupa	terramoto	fauno	cachalote	reife	catapinha
tarde	diferença	dedal	indigesto	vesna	nargativa
papel	dirigente	vesgo	cabotagem	vorfa	reditagem
filme	ginástica	jaspe	cavalgada	moliz	caxaltiça
total	ginástica	lorpa	repetente	begor	pelorente
líder	eleitoral	ginja	campesino	férus	repelanto
dólar	casamento	sapal	dirigismo	tolim	giritento
feliz	municipal	lúpus	petulante	vimol	dipetendo
vírus	resultado	móbil	pilotagem	sárus	renimenca
rival	chanceler	bemol	carrascão	mópis	chuvercar
vital	calcanhar	bilro	bairrista	pamur	sustincar

High Frequency (HF)		Low Frequency (LF)		Pseudoword (PW)	
lápis	suspensão	selim	chamuscar	sezir	caquinhar
luzir	banqueiro	bílis	charneira	xorba	fangarrão
civil	linguagem	fémur	churrasco	ripel	carfascão
arroz	distinção	lince	carrossel	sadal	pegulante
nuvem	mesquinho	furna	fanfarrão	pazol	jesquinho
grupo	finlandês	lugre	casquilho	zegre	mistinção
fluxo	charneira	sabre	metralhar	flubo	proguiste
negro	orquestra	zebra	doutrinal	labro	castrapal
lapso	principal	tripé	chanfrado	rubre	prolhando
rubro	proporção	brejo	castrense	glopo	disgrital
lebre	brilhante	greda	flautista	gnoxo	mepralhar
globo	distrital	gnomo	droguista	brepo	casprense

Figure 01.TIF

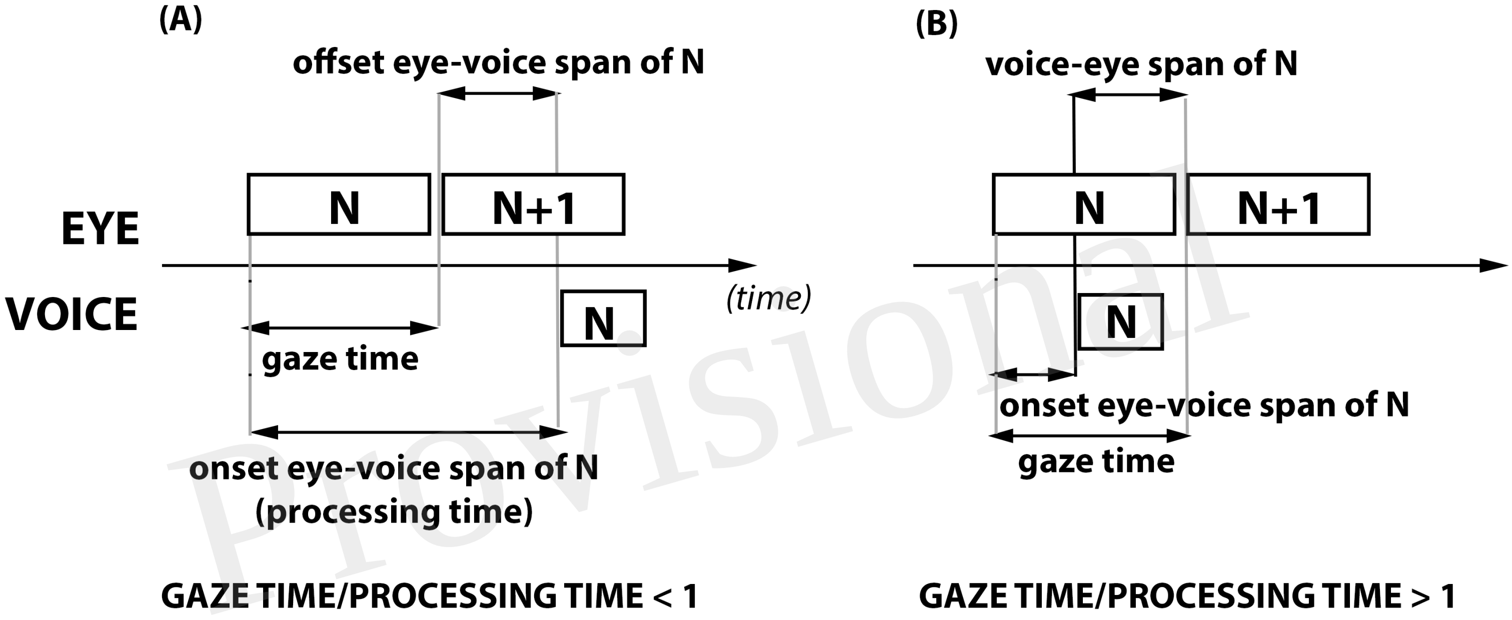

Figure 02.TIF

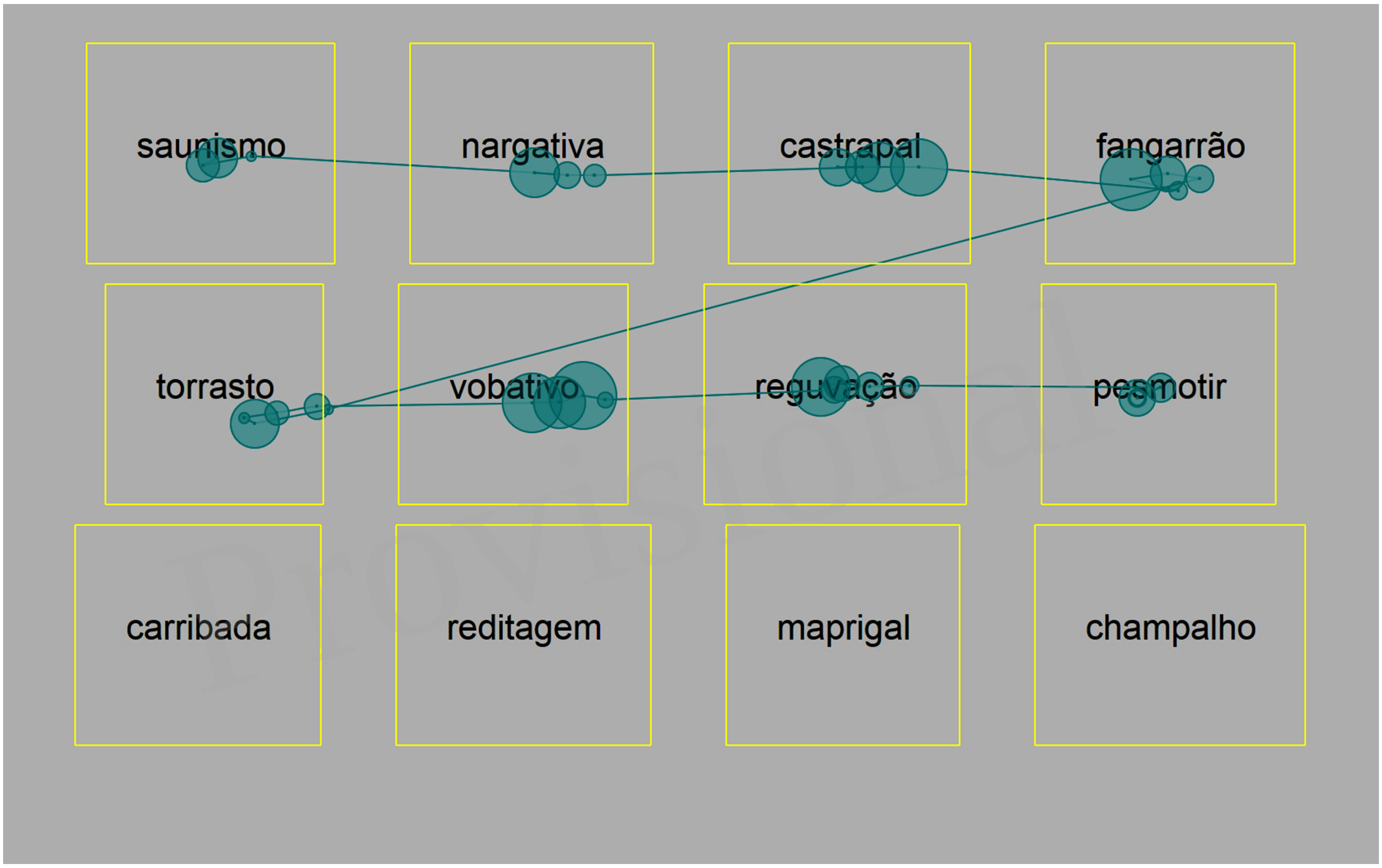

Figure 03.TIF

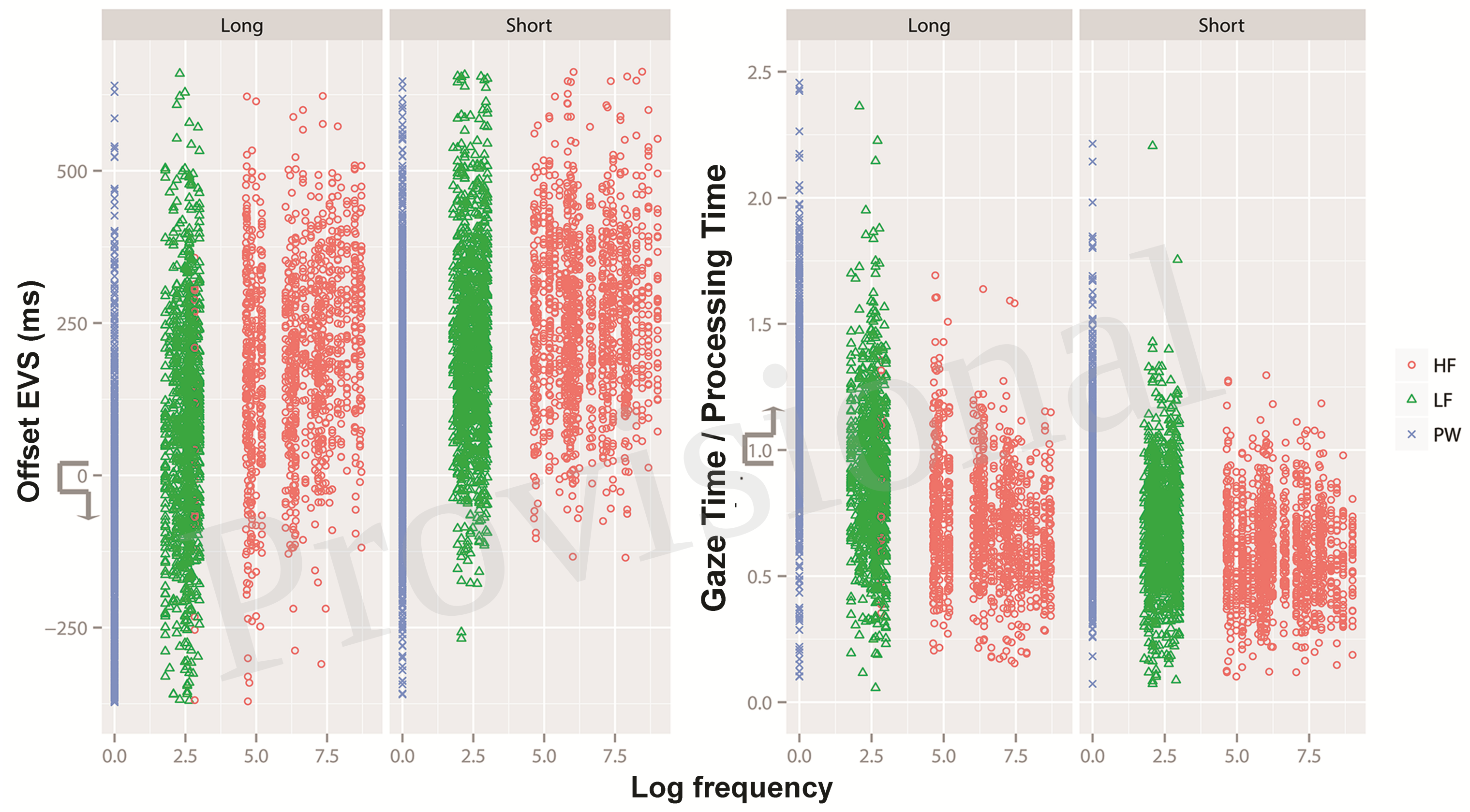

Figure 04.TIF