

Transposed-letter Neighbor Effects on Different Syllabic Positions on a Lexical Decision Task

Efeito de vizinho transposto em diferentes posições silábicas em uma tarefa de decisão lexical

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Abstract: This study examined the effect of transposed-letter neighborhood (TLN) in different syllabic positions during visual word recognition in Brazilian Portuguese. For this, we conducted two experiments. In the first experiment, 40 college students took part in a lexical decision task with masked priming. The stimuli — disyllabic words and pseudowords — were primed by a nonword created by transposing two letters of the target stimulus. The letter transpositions occurred in different syllabic positions: within the first syllable, within the second syllable, or between the first and second syllables. A control condition with no prime was also included. The dependent variable was reaction time in determining whether the stimulus was a word or not. In the second experiment 31 college students took part in the study, and the control condition involved an identity prime. The results from both experiments revealed that the experimental conditions differed significantly from the control but did not differ statistically among themselves. These results suggest that TLN effects do not vary according to syllabic position. This absence of interaction was interpreted in the light of dual-route models of reading, suggesting that the orthographic route plays a primary role in the TLN effect.

Keywords: visual word recognition; syllable position; transposed-letter neighborhood; lexical decision; reading.

Resumo: Este estudo investigou o efeito de vizinhos transpostos (TLN) em diferentes posições silábicas durante o reconhecimento visual de palavras no português brasileiro. Para isso, realizamos dois experimentos. No primeiro experimento, 40 estudantes universitários



participaram de uma tarefa de decisão lexical com *priming*. Os estímulos — palavras dissílabas e pseudopalavras — foram precedidos por uma não-palavra criada pela transposição de duas letras do estímulo alvo. Essa transposição ocorreu em diferentes posições silábicas: na primeira, na segunda e entre a primeira e a segunda sílaba. Uma condição controle sem *prime* também foi incluída. A variável dependente foi o tempo de reação para determinar se o estímulo era ou não uma palavra. No segundo experimento, 32 estudantes universitários participaram do estudo, e a condição de controle utilizada foi o *prime* de identidade. Os resultados de ambos os experimentos mostraram que as condições experimentais diferiram da condição controle, mas não diferiam estatisticamente umas das outras. Esses resultados sugerem que os efeitos de TLN não variam com a posição silábica. Essa falta de interação foi interpretada à luz dos modelos de dupla rota de leitura, sugerindo que a rota ortográfica é a principal responsável pelo efeito de vizinhos transpostos (TLN).

Palavras-chave: reconhecimento visual de palavras; posição silábica, vizinhos transpostos; decisão lexical; leitura.

1 Introduction

One of the most researched topics in psycholinguistics and cognitive psychology is skilled reading (Yates; Dickinson, 2023). In reading, lexical access refers to access to the mental representation of a word, which is a fundamental process for building good text comprehension (Perfetti; Hart, 2001). Understanding which variables influence lexical access can improve psycholinguistic models of visual word recognition and contribute to a better understanding of reading disorders (Rayner *et al.*, 2012). These variables can be lexical or sublexical. Examples of sublexical variables are the syllables and the morphemes of a morphological complex word. Examples of lexical variables are the frequency of occurrence of a word in a respective language and the degree of orthographic similarity of a word with other words. The degree of orthographic similarity can be measured by the number of orthographic neighbors – N (Coltheart *et al.*, 1977). N indexes the number of words that share the same letters and letter's position with the target word, except for one of these letters. For example, in Brazilian Portuguese, the target word '*canela*' (cinnamon) has seven orthographic neighbors: '*janela*' (window), '*panela*' (pan), '*cadela*' (bitch), '*capela*' (chapel), '*canola*' (canola), '*caneca*' (mug), and '*caneta*' (pen). Another measure of orthographic similarity is the number of transposed-letter neighbors of a word – TLN (Andrews, 1996), which refers to the words that can be formed

by the transposition of two neighbor letters within a word (e.g., the words '*anual*' (annual) and '*anula*' (annul) in Brazilian Portuguese). TLN effects have been studied through different techniques and tasks (Acha and Perea, 2008; Andrews, 1996; Humphreys *et al.*, 1990; Johnson, 2009; Meade *et al.*, 2021; Perea; Lupker, 2003a, 2003b).

One of the first studies that systematically investigated the TLN effect was conducted by Andrews (1996). In this study, she conducted a series of experiments manipulating TLN. A Lexical Decision Task – LDT was employed in one of these experiments. In a LDT, a stimulus is displayed on the computer screen, and the subject must answer, as quickly and accurately as possible, if the stimulus displayed is or is not a known word. In this experiment, TLN was manipulated, and lexical frequency, bigram frequency and the number of orthographic neighbors were controlled. The results showed that both words and pseudowords (letter sequences that follow the phonotactic rules of a language and can be pronounced) with TLN were recognized more slowly than those without TLN. Andrews argued that the inhibitory effect of TLN is compatible with the lateral inhibition mechanisms of the interactive activation models (Grainger; Jacobs, 1996; McClelland; Rumelhart, 1981). In these models, exposure to the target word would also activate its transposed letter neighbor to some degree, generating competition between them during lexical access, thus leading to longer reaction times. The TLN inhibitory effect was also found in eye-tracking studies during silent reading (Acha; Perea, 2008; Johnson, 2009). For example, Acha and Perea (2008) observed an increased number of regressions back to the target word and a higher total fixation time for words with TLN than for words without TLN.

Another technique used to investigate the TLN effect is priming (Andrews, 1996; Humphreys *et al.*, 1990; Meade *et al.*, 2021; Perea; Lupker, 2003a, 2003b). In tasks using the priming technique, the target stimulus is preceded (primed) by another stimulus that can be perceptible or not, depending on the time of exposure. When a transposed neighbor primes the target stimulus, a word or a pseudoword, such as the word '*ABOLIR*' (abolish) primed by the pseudoword '*abloir*', the target stimulus is recognized faster by the subjects (e.g., Humphreys *et al.*, 1990; Perea; Lupker, 2003b) in comparison with an orthographic control condition (e.g., '*ABOLIR*' primed by '*abteir*').

In view of all this, a question arises: why does the transposed neighbor play an inhibitory role in lexical decision tasks and a facilitatory role in priming tasks? The answer is that the effect would depend on the interactive activation dynamics of the models and the task demands. In theoretical models based on interactive activation (e.g., Grainger; Jacobs, 1996; McClelland; Rumelhart, 1981), there is a competition to find the correct lexical entry among a group of candidates. Thus, on lexical decision tasks, the search for the correct lexical entry between the target and its transposed letter neighbor would slow down lexical access (e.g. the target word '*garça*' (egret) would compete for recognition with its transposed neighbor '*graça*' (grace). Meanwhile, on tasks with priming, once the target word is primed by its transposed neighbor, it would pre-activate the target word among the other possible candidates, facilitating its later recognition (e. g, the prime '*abloir*' would facilitate the processing of the target '*abolir*' (abolish).

Another variable that has been studied in the lexical access context is the syllable (Álvarez *et al.*, 2004; Ashby; Rayner, 2004; Campos *et al.*, 2018, 2020; Carreiras *et al.*, 1993; Chetail; Mathey, 2009a, 2009b; Conrad; Jacobs, 2004; González-Alvarez; Palomar-García, 2016; Justi; Justi, 2017, 2018; Luque *et al.*, 2021; Montani *et al.*, 2019). The syllable, a sub-lexical variable, is defined phonologically as a speech segmentation unit present in various langua-

ges. One of the first studies investigating the syllable effect on lexical access was conducted by Carreiras *et al.* (1993). In this study, conducted with fluent Spanish readers, the frequency of occurrence of the first syllable was manipulated at two levels - low and high frequency of occurrence - in a series of five experiments using lexical decision and reading aloud tasks. Overall, the authors found an inhibitory effect of the syllable frequency on visual word recognition in Spanish; the more frequent the syllable, the more slowly the word was recognized. It is important to point out that the frequency of occurrence of bigrams, a variable that measures the co-occurrence of letter patterns in the lexicon of a language, was controlled since, according to the orthographic redundancy hypothesis (Seidenberg, 1987, Seidenberg; McClelland, 1989), syllable effects would be merely illusory (Carreiras *et al.*, 1993). Therefore, once the frequency of bigrams was controlled in the study, the syllable effects could not be explained by the orthographic redundancy hypothesis. Thus, authors hypothesized that, during lexical access, a word would activate other words which share its' first syllable, and, therefore, a word with high syllabic frequency would be recognized slower than a word with low syllabic frequency because the former would be selected among a larger set of candidates.

Conrad and Jacobs (2004) conducted a study to investigate whether the syllabic frequency effect would also occur in German, a language that, like Spanish, has a high degree of transparency in its grapheme-phoneme mapping. They conducted two experiments, one with a lexical decision task and another with a perceptual identification task. In the perceptual identification task, stimulus identification was made difficult by the fragmentation of all the letters of the word (only 12% of the visual characteristics of each stimulus were initially visible on the computer screen). The participants were instructed to press a button to activate more visual characteristics of the stimulus. Each time they pressed the button there was a 12% increase in the visual characteristics of the stimulus until they could recognize the target word. Once they identify the word, they should type it. A 2x2 factorial manipulation of the frequency of occurrence of the word — high x low — and frequency of occurrence of the first syllable — high x low — was employed. The authors found an inhibitory effect of syllabic frequency in both the lexical decision task and the perceptual identification task.

The syllable effect has also been found in languages with less consistent grapheme-to-phoneme mappings, such as French (Chetail; Mathey, 2009a, 2009b) and English (Ashby; Rayner, 2004). The syllabic frequency is a variable that generally presents inhibitory effects on visual word recognition (Carreiras *et al.*, 1993; Conrad; Jacobs, 2004; Chetail; Mathey, 2009b) and auditory word recognition (González-Alvarez; Palomar-García, 2016). However, in tasks using the prime technique, when target words are preceded by stimuli that share the same initial syllable as they do, the syllable tends to present a facilitative role when compared with other conditions (Álvarez *et al.*, 2004; Campos *et al.*, 2020; Chetail; Mathey, 2009a; Just; Just, 2017). In this case, a prime with the same initial syllable as the target word would pre-activate the target word among the possible candidates in the lexicon, facilitating its subsequent recognition. In this sense, the study by Chetail and Mathey (2009a) sought to investigate the effect of syllabic frequency on tasks with priming in French. To do so, they employed a lexical decision task and a reading-aloud task. The display time of the priming was manipulated in two levels: 43ms and 67ms. The target words were preceded by stimuli that shared its first two/three letters, which may correspond to its syllable in the congruent condition (e.g., 'pa****' - 'pa.lace' or 'pal****' - 'pal.mier') or not, in the incongruent condition (e.g., 'pal****' - 'pa.lace' or 'pa****' - 'pal.mier'). Assuming that syllable does not affect lexical access, the

primes sharing more letters with the target stimulus would pre-activate more orthographic units of the target word and facilitate its processing, regardless of the condition — congruent or incongruent. The results showed that the targets in the congruent prime condition were recognized significantly faster than in the incongruent prime condition, regardless of the type of task — lexical decision or reading aloud. However, this effect interacted with the duration of the prime, as there was only a syllabic frequency effect when the prime duration was 67ms. Finally, Chetail and Mathey (2009) concluded that the results support the hypothesis that syllables are functional units of lexical access in French.

Given the relevance of syllabic frequency and TLN effects on lexical access, Justi and Justi (2018) investigated these variables in Brazilian Portuguese. Two experiments were conducted to investigate this issue. The first consisted of a lexical decision task in which the stimuli were words or pseudowords. The words corresponded to a 2x2 factorial manipulation of TLN — no transposed neighbors x with one transposed neighbor — and syllabic frequency — low x high frequency of occurrence of the first syllable. A corresponding manipulation was made for the pseudowords. The authors observed an inhibitory effect of TLN for both words and pseudowords (that is, stimuli with one transposed neighbor were recognized slower than those without transposed neighbors). In addition, an inhibitory effect of syllabic frequency was observed only for the pseudowords. However, the main finding was that there was no significant interaction between TLN and syllabic frequency. The second experiment consisted of a perceptual identification task using the same words employed in the previous experiment. The results showed a significant inhibitory effect of syllabic frequency, in which there was less accuracy for words initiated with high-frequency syllables when compared with words initiated with low-frequency syllables. However, there was no statistically significant TLN effect. It is important to note that in both experiments, there was no significant interaction between TLN and syllabic frequency.

To follow up on the research of Justi and Justi (2018) that investigated the relationship between TLN and syllabic frequency in Brazilian Portuguese, the present study aimed to investigate whether the effect of TLN varies according to the syllabic position in which the transposed neighbor occurs. For this, a lexical decision task with prime was used, having the reaction time as a dependent variable. Since a transposed-letter neighbor will precede the target stimulus, it is expected that TLN, in this case, will present facilitative effects on the processing of the target stimulus, as predicted for other languages. In addition, since Justi and Justi (2018) did not detect an interaction between TLN and syllabic frequency, we expect to replicate this absence of interaction by now considering a new variable which is the syllabic position in which TLN occurs; in the first syllable, in the second syllable or between syllables. This research is essential because some visual word recognition models assume an explicit level of syllabic representation (e.g., Conrad *et al.*, 2010), whereas other models do not (e.g., Whitney, 2001). Thus, the present study results can be used to constrain models of visual word recognition devised to explain syllabic frequency and transposed letter effects.

2 First experiment

2.1 Method

2.1.1 Sample

Forty young college students from the institute of human sciences of the Federal University of Juiz de Fora participated in this study, consisting of twenty-three women and seventeen men, all native speakers of Brazilian Portuguese. All participants signed an informed consent form, agreeing to participate in the study. This study was approved by the Ethics Research Committee of the authors' institution.

2.1.2 Design

The present study included two independent variables: stimulus type — word or pseudoword — and prime type: first syllable TL prime, second syllable TL prime, between syllables TL prime, and no prime (control condition). These variables were manipulated within subjects in a 2x4 factorial design. The dependent variable was the participants' reaction time.

2.1.3 Materials

The experimental stimuli consisted of 60 dissyllabic words and 60 dissyllabic pseudowords. All stimuli were between four to six letters long and had neither transposed neighbors (TLN) nor orthographic neighbors (N). The words had a mean frequency of occurrence per million of 11,4 (Justi; Justi, 2008), a mean frequency of occurrence per million of their first syllable of 535,3, and a mean bigram frequency (token) of 958,4 (Justi; Justi, 2009). The pseudowords were created by the experimenter and had a mean frequency of occurrence per million of their first syllable of 445 and a mean bigram frequency (token) of 825,4 (Justi; Justi, 2009).

Except for the control condition, target-stimuli were always primed by a transposed letter prime (e.g., in an experimental condition, the target word 'FRETE' would be primed by 'ferte', or the target pseudoword 'FRUBE' would be primed by 'furbe'). Such transposition could occur on different syllabic positions, according to the following experimental conditions: (1) prime with letter transposition on the first syllable (e.g., prime 'xepor', target 'EXPOR'); (2) prime with letter transposition on the second syllable (e.g., prime 'expro', target 'EXPOR'); (3) prime with letter transposition between first and second syllable (e.g., prime 'epxor', target 'EXPOR'); and, (4) control condition (e.g., no prime, target 'EXPOR'). The variable 'priming condition' was manipulated within subjects, with 15 words and 15 pseudowords in each of the four experimental conditions mentioned above, thus totaling the 120 stimuli.

The 60 words were counterbalanced, among four groups of 15 words each, based on the frequency of occurrence, frequency of their first syllable and bigram frequency. In the same way, the 60 pseudowords were counterbalanced among four groups of 15 items, each based on the frequency of their first syllable and bigram frequency. An analysis of variance indicated that there was no statistically significant difference among the word groups for word frequency, frequency of first syllable and bigram frequency (all $p > .90$). In addition,

there was no statistically significant difference among the pseudoword groups for frequency of the first syllable and bigram frequency (all $p > .90$). These groups of words and pseudowords were fully crossed with the four priming conditions generating four Lists: List 1 (group 1 = first syllable prime, group 2 = second syllable prime, group 3 = between syllables prime, and group 4 = no prime); List 2 (group 1 = no prime, group 2 = first syllable prime, group 3 = second syllable prime, group 4 = between syllables prime); List 3 (group 1 = between syllables prime, group 2 = no prime, group 3 = first syllable prime, group 4 = second syllable prime); and, List 4 (group 1 = second syllable prime, group 2 = between syllables prime, group 3 = no prime, group 4 = first syllable prime).

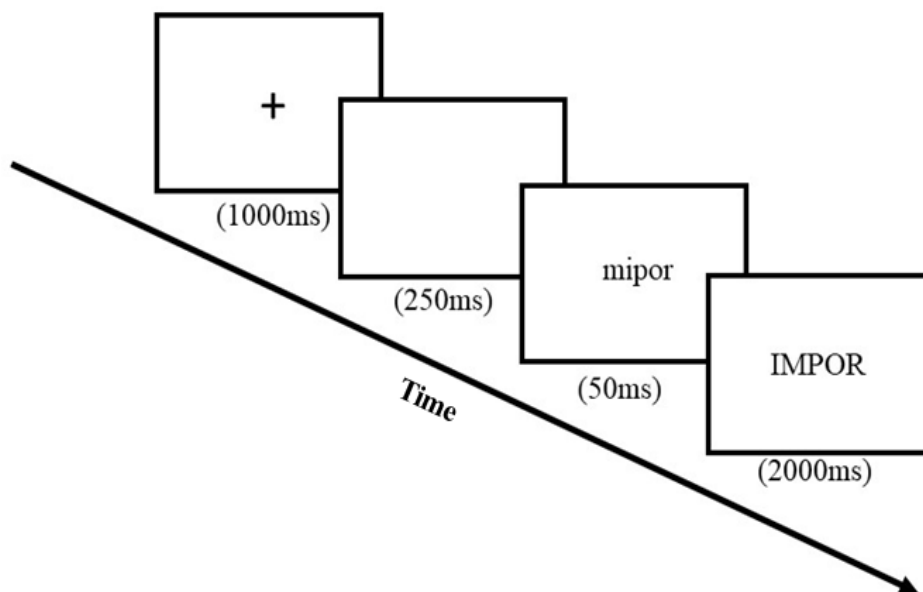
2.1.4 Procedure

Participants were tested individually with up to four people at the Experimental Psychology Laboratory of Federal University of Juiz de Fora. Each participant was randomly attributed to one of the four lists according to their chosen computer. The software E-PRIME v.2.0 PROFESSIONAL (Zuccolotto *et al.*, 2012) was used for stimuli presentation and reaction time (RT) data acquisition. Before starting the experiment, subjects were instructed that words, real or invented, would be displayed on the computer screen, and they were asked to judge as quickly and accurately as possible by pressing the “z” key for words and the “y” key for invented words (pseudowords).

Stimuli were presented on the center of the computer screen, and participants were not informed about the priming. Stimuli were presented in the following steps. First, a fixation mark (+) was presented for 1,000ms, followed by a blank screen for 250ms. The prime, in lowercase letters, followed the blank screen for 50ms; then, the target stimulus was presented in uppercase letters for 2000ms. The intertrial interval was 1,000ms. The total length of each trial was the same in all conditions. Before the presentation of the target stimulus in the control condition (no prime), the prime was replaced by a blank screen lasting the same length as the primes (50ms).

All stimuli were presented in the font “Courier New” and size 14. The font color was black, and the background was white. Figure 1 illustrates the experimental sequence of stimuli exhibition. Each participant received eight practice trials prior to the 120 experimental trials to get used to the buttons and stimuli. The practice session was repeated if the participants had an accuracy lower than 80%, and all stimuli were presented randomly for each participant. The experimental session lasted approximately 15 minutes.

IMAGE 1 – Experimental sequence of stimuli in the lexical decision task



Note: On the illustration, the target-stimulus 'IMPOR' is primed by the stimulus 'mipor'

Source: own elaboration.

2.2 Results

The participants had a mean accuracy of 96% on the lexical decision task. Table 1 presents the mean RT per experimental condition. Based on Kolmogorov-Smirnov Z tests (all p values $> 0,15$), it is possible to assume that the reaction time data is normally distributed.

For data analysis, a 2x4 ANOVA was performed on participants' reaction time (RT) data, in which the within-subject factors were 'stimulus type' — words or pseudowords — and 'prime type' — first syllable TL prime, second syllable TL prime, between syllables TL prime, and no prime. The main effect of stimuli type was statistically significant, $F(1,39) = 76,26$, $p < 0,001$, resulting from the fact that words were recognized 116ms faster than pseudowords. Also, a TLN general effect was revealed, $F(3,117) = 8,65$, $p < 0,001$, indicating that there was a statistically significant difference between the control condition (without prime) and the other experimental conditions in which a TL prime was present (all $p < .01$). However, no statistically significant differences were found among TL prime positions; that is, no differences in RT were observed between the conditions: first syllable TL prime, second syllable TL prime, and between syllables TL prime (all $p > .13$). No interaction between the stimulus type and prime type were found, $F(3,117) = 1,03$, $p = 0,38$.

Table 1 – Mean RT in milliseconds and standard deviation (SD) per experimental condition on Experiment 1 Lexical Decision Task.

Prime	No prime	1° Syllable TL prime	Between syllables TL prime	2° Syllable TL prime
Word				
RT, M (SD)	644 (96)	669 (89)	667 (102)	671 (95)
Pseudowords				
RT, M (SD)	759 (148)	797 (150)	787 (140)	775 (144)

Source: own elaboration.

2.3 Discussion

As predicted (e.g., Forster; Chambers, 1973; Justi; Justi, 2017; Monsell *et al.*, 1992), the traditional effect of lexicality was observed; words were recognized more quickly than pseudowords. Also, the main effect of prime type was observed, in which stimuli preceded by transposed neighbors were recognized more slowly than those without prime. More importantly, there was no difference in the priming effect according to the syllabic position in which the transposed letter neighbor occurred. The absence of variation of TLN effects by syllabic position was expected here because of the results of Justi and Justi (2018), who investigated the relationship between TLN and syllabic frequency in Brazilian Portuguese and found no interaction between these variables. It is important to note that while the study of Justi and Justi (2018) used syllabic frequency to investigate the syllabic effect, the current study used another measure related to syllabic processing, the syllabic position. Thus, the current study expands the evidence that the factors involved with the TLN effect do not interact with those involved in syllabic processing.

One difference between the present study results and the results of other studies is the TL prime effect. In other studies, the TL prime had a facilitative effect on target recognition (Andrews, 1996; Humphreys *et al.*, 1990; Meade *et al.*, 2021; Perea; Lupker, 2003b); however, in the present study, there was an inhibitory effect of the TL prime in comparison with the no prime control condition. It is important to note, however, that previous studies investigating the effect of TLN employed unrelated primes as a control condition — e.g., the prime “abteq” preceding the target “impor” (impose) — or orthographic primes with one or more letter substitutions — e.g., the prime “istor” preceding the target “impor” (impose). We opted not to use those kinds of primes as a control condition because it is possible to argue that the control condition exerts an inhibitory or facilitative effect and not the experimental variables (Guerrera; Forster, 2008). For example, it is possible to argue that the unrelated prime (control condition) inhibits the target instead of arguing that the TL prime facilitates the target recognition. Another issue would be how to guarantee that the substitution primes used as controls are equivalent among the lists. For example, it could be easier to generate orthographically

legal substitution primes in the last syllable than in the first; thus, the control conditions for the first syllable TL prime and the second syllable TL prime would not be equal. To circumvent these problems we employed a second experiment using identity primes as control (e.g., the prime 'casa' (house) for the target 'casa') as this guarantees that the control conditions for all types of transposed letter primes are equivalent.

Studies that evaluated TL primes compared to control identity primes found that stimuli preceded by TL primes presented equal or higher reaction times than stimuli preceded by identity primes (Humphreys *et al.*, 1990; Perea; Lupker, 2003b). Thus, in the second experiment, the identity prime was used as a benchmark for assessing the extent of priming observed for the different experimental conditions. If the TL prime effect varies according to its syllabic position, then statistically significant differences in reaction time are expected among the TL prime conditions — first syllable, second syllable, and between syllables —, and the degree of inhibition in comparison to the identity prime condition would work as an index of the strength of TL prime effects.

3 Second experiment

3.1 Method

3.1.1 Sample

Thirty-one young college students from the institute of human sciences of the Federal University of Juiz de Fora participated in this study, consisting of twenty-six women and five men, all native speakers of Brazilian Portuguese. All participants signed an informed consent form, agreeing to participate in the study. This study was approved by the Ethics Research Committee of the authors' institution.

3.1.2 Design, materials and procedures

The design, materials, and procedures were the same as in Experiment 1, with the sole exception that the control condition was replaced by a control condition with identity prime (the prime stimulus and the target stimulus are the same). For instance, in the identity prime condition, the word 'impor' (impose) was primed by 'impor'.

3.2 Results

The participants had a mean accuracy of 95% on the lexical decision task. Table 2 presents the mean RT per experimental condition. Based on Kolmogorov-Smirnov Z tests (all p values > 0,4), it is possible to assume that the reaction time data is normally distributed.

A 2x4 ANOVA was performed on participants' reaction time (RT) data, in which the within-subject factors were 'stimulus type' — words or pseudowords — and 'prime type' — first syllable TL prime, second syllable TL prime, between syllables TL prime, and identity prime.

The main effect for stimuli type was statistically significant, $F(1,30) = 92,60$, $p < 0,001$, resulting from the fact that words were recognized 147ms faster than pseudowords. Also, a main TL prime effect was revealed, $F(3,90) = 9,36$, $p < 0,001$, indicating that there was a statistically significant difference between the control condition (identity prime) and the TL prime conditions (all $p < .01$). However, no statistically significant difference among the TL prime positions were found, that is, no significant differences in RT were observed among the conditions: first syllable TL prime, second syllable TL prime, and between syllables TL prime (all $p > .5$). No interaction between the stimulus type and prime type were found, $F(3,90) = 1,81$, $p = 0,15$.

Table 2 - Mean RT in milliseconds and standard deviation (SD) per experimental condition on Experiment 2 Lexical Decision Task.

Prime	Identity prime	1° Syllable TL prime	Between syllables TL prime	2° Syllable TL prime
Word				
RT, M (SD)	620 (109)	680 (97)	664 (102)	676 (101)
Pseudowords				
RT, M (SD)	785 (135)	810 (153)	820 (179)	815 (159)

Source: own elaboration.

3.3 Discussion

As in Experiment 1, the effect of lexicality (Forster; Chambers, 1973; Justi; Justi, 2017; Monsell *et al.*, 1992) was observed, with faster recognition times for words compared to pseudowords. A main prime effect was also observed, where the TL prime conditions resulted in slower reaction times in comparison with the identity prime control condition. The inhibitory effect of TLN, when compared to the identity prime condition, is expected and aligns with previous studies (e.g., Humphreys *et al.*, 1990; Perea; Lupker, 2003b). More importantly, as in Experiment 1, no significant differences were found among the TL prime conditions — 1st syllable TL prime, 2nd syllable TL prime, and between syllables TL prime —, demonstrating that the TL prime effect does not depend on the syllabic position of the letter transposition. Thus, Experiment 2 extends the findings by Justi and Justi (2018) which did not observe any interaction between TLN and 1st syllable frequency in their study.

4 General Discussion

This study aimed to investigate if the effect of TLN varies according to its syllabic position in Brazilian Portuguese, using a lexical decision task with the priming technique. The results showed no interaction between TLN and syllabic position. This result aligns with the fin-

dings of Justí and Justí (2018), who similarly found no interaction between TLN and syllabic frequency (SF), another variable that measures syllabic processing. Thus, the result of this study expands the evidence that the effects of syllables and TLN are variables ruled by independent processing mechanisms.

Considering the existence of syllabic effects in Brazilian Portuguese visual word recognition (see, e.g., Justí; Justí, 2018 for syllabic frequency effects in adults, and Justí; Justí, 2017 for syllabic priming effects in children), a possible explanation for the lack of variation in TL prime effects according to their syllabic position is related to the temporal processing of orthographic and phonological information, with orthographic information being processed earlier in visual word recognition. For example, Chetail and Mathey (2009) observed syllabic frequency effects in French only with 67ms primes, while no effects were found with 43ms primes. This same syllabic frequency effect in function of time (43ms x 67ms) was replicated in Spanish by Grainger *et al.* (2003). Meanwhile, the present study found TL prime effects with only 50ms of prime exposition in two different experiments and in comparison with two different control conditions, but with no variation according to their syllabic position. Therefore, the present study demonstrates that the effects of transposed letter primes occur as early as 50ms and are not sensitive to syllabic position.

In addition to prime studies, an ERP study by Grainger *et al.* (2006) also corroborates the early effects of orthographic processing in visual word recognition. In this study, words were preceded by orthographic, phonological, and control primes, all lasting 50ms. Neuroimaging results indicated that phonological and orthographic primes activated distinct cortical areas and occurred at different times, with the orthographic effect emerging first. Similar findings were observed in an ERP study with priming in Spanish (Carreiras *et al.*, 2009).

Considering theoretical models of visual word recognition, the results of the present study support the notion that transposed letter neighbors affect early phases of visual word recognition related to orthographic processing of letter order (e.g., Grainger, 2008; Whitney, 2001; Whitney *et al.*, 2012). The absence of syllabic position effects for the TL prime in the present study, together with evidence that the syllabic priming effect has been observed only when the prime has a duration higher than 50ms (see, e.g., Chetail; Mathey, 2009; Justí; Justí, 2007; Grainger *et al.*, 2003) is in accordance with visual word recognition models which assume, in addition to an orthographic route, a slower phonological independent route in reading (e.g., the model by Coltheart *et al.*, 2001). More specifically, these results are in accordance with the model by Conrad *et al.* (2010), which explicitly assumes an independent syllabic route. In short, the absence of syllabic position effects in the present study corroborates the hypothesis that the TLN effect and the syllabic effect are ruled by distinct routes, with the TLN effect being ruled primarily by the orthographic route (Justí; Justí, 2018).

Statement of Authorship

This study is based on data collected for Lucas Silveira Santiago's undergraduate thesis, supervised by Francis Ricardo dos Reis Justí. It is part of the broader research project "Orthographic Similarity and Syllabic Frequency in Different Lexical Access Tasks" (financed by CNPq / 443445/2014-1) designed by the second author. The first author was responsible for data collection and the initial drafting of the manuscript. The second author designed

the experimental paradigm and conducted the statistical analyses. Both authors contributed to programming the experiment in E-Prime 2.0, creating of the stimuli, interpreting the data and discussing the findings.

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