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CROSS-LINGUISTIC PRIMING EFFECTS DURING THE COMPREHENSION OF THE PASSIVE VOICE: TWO PRIMES ARE ENOUGH

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Abstract

The present study investigated cross-linguistic structural priming effects from L1 to L2 during the comprehension of the passive voice in a group of 35 Brazilian Portuguese-English (BP-EN) late bilinguals. A 4 x 2 experimental design was implemented that included a four levels within-subjects Condition variable and a between-subjects Proficiency variable (Intermediate vs. Advanced). Results show that, regardless of proficiency, participants read target sentences faster in both experimental conditions when compared to the control conditions. Noticeably, cross-linguistic structural priming effects were observed even in the absence of translation equivalents. That is, both abstract and lexically mediated structural cross-linguistic effects were observed. These findings indicate that late bilinguals at intermediate and advanced levels of proficiency have a shared syntactic system between their L1 and L2.

Keywords: structural priming; bilingual language processing; comprehension; Brazilian-Portuguese; residual activation

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1. Introduction

According to the Ethnologue's most recent report, published in 2021, there are approximately 1,076,766,120 non-native speakers of English around the globe. This makes English the most popular second language in the world followed by Modern Standard Arabic, with 273,989,700 L2 speakers, and Hindi, with 258,266,900 L2 speakers (Eberhard, Simons & Fenning, 2023). In Brazil, Spanish is believed to be the most common second language with an estimated amount of 5,234,160 non-native speakers (Instituto Cervantes, 2022). Regardless of the specific language we are interested in, these data support the claim that bilingualism is the norm rather than the exception (Grosjean, 2008, 2010, 2013; Kroll, et al., 2012; Kroll & Navarro-Torres, 2018; Godfroid & Hopp, 2023).

Importantly, as already argued by Grosjean in 1989, bilinguals are not two monolinguals in one. In fact, being bilingual brings unique consequences to aspects of cognition that go even beyond language (Peal & Lambert, 1962; Li et al., 2014; Rothman et al., 2021). Within the language-related idiosyncrasies of bilingualism, bilinguals not only mentally represent the knowledge of their languages, but they also activate these representations during everyday language use, selecting some and inhibiting others (Kroll et al., 2006; Paap, 2019). Thus, the architecture of the bilingual language system must accommodate representations in a way that optimizes efficiency.

Even though languages differ in many aspects, they are similar in many others. For instance, the structure of the passive voice in Brazilian Portuguese and English is quite similar. Both languages share the same word order: the main verb is preceded by an auxiliary verb and the optional by-preposition comes at the end of the sentence.

(1) a. *O menino foi abraçado pela mãe.*
b. The boy was hugged by the mother.

In this particular case, one might wonder how the bilingual language system would be organized. One option is that two different representations would be implemented, one referring to the passive voice in BP and another referring to the passive voice in EN. Another alternative is that structures that exist in both languages and are similar enough (e.g. share the same word order) would be represented only once.

In the present study, we were particularly interested in how BP-EN late bilinguals represent and process the EN passive voice. In order to address this question, we turned to a well-established experimental paradigm: the structural priming paradigm. Broadly speaking, in a structural priming study, researchers look for facilitation effects that processing a prime sentence may have on the subsequent processing of a target sentence (Bock, 1986; Branigan & Gibb, 2018). In the case of bilingual language processing, if processing a prime sentence with a determined syntactic structure in one language is shown to facilitate the

processing of a target sentence containing the same structure in another language, then the issue of how bilinguals represent their L2 begins to be resolved: priming effects can only rise if L1 and L2 structures are shared.

2. Priming as a window into the bilingual language system

In 1986, Kathryn Bock published a paper in which she investigated language users' tendency to repeat the same syntactic structures across multiple sentences. This seminal study showed that participants were more likely to use a given syntactic structure when describing a picture if they had just encountered that structure. For example, after hearing and repeating a passive sentence, participants were more likely to use the passive structure to describe an unrelated picture. Bock (1986) interpreted this tendency to reuse syntactic structures as indicative of a biased sentence formulator. That is, the probability of producing a passive sentence was increased by having just heard and repeated the same passive structure. The effect of facilitation that the first sentence, the prime, had upon the other, the target, was referred to as the syntactic or structural priming effect.

In 2003, Loebell and Bock conducted the first structural priming study across languages. Their study was an adaptation of Bock (1986) and the structures they were interested in were datives (double-object and prepositional) and transitive (active and passive) sentences. In the prime phase of the experiment, participants listened and repeated an English or a German sentence. Then, they were asked to describe an unrelated image. The results showed that syntactic priming effects could indeed happen between languages: the production of German dative sentences primed the production of English datives, and the production of English datives primed German datives. However, passive sentences did not yield the same results in either direction. One possible explanation is that even though priming between languages exists, it only occurs when the structure in both languages is similar enough, for instance, when they share the same word order. This is not the case for English and German passive sentences.

In a series of studies with Spanish-English bilinguals with moderate or high L2 proficiency, Hartsuiker and colleagues (2004) found similar results. Participants were asked to describe pictures after having heard a confederate, disguised as a participant, do the same. The confederate, while pretending to be describing a picture, provided participants with the prime sentence. The structures investigated were active, passive, intransitive and OVS (object - verb - subject). Priming effects were only found for the passive structure. Importantly, the authors explain that these results may be due to the fact that only in the passive structure English and Spanish share the same word order.

The results yielded in those studies shed light on what might be an important moderator of cross-linguistic syntactic priming effects: word order repetition. In this sense, Bernolet and colleagues (2007) found both intra and cross-linguistic syntactic priming effects. However, cross-linguistic priming effects during production were found to be dependent upon word order repetition. Indeed, as

to increase the likelihood of finding cross-linguistics priming effects the present study used a syntactic structure that has the same word order in both BP and EN: the passive voice.

Also investigating how bilinguals process the passive voice, Gámez and Vasilyeva (2019) conducted a cross-linguistic priming study with balanced bilinguals. Participants were six-year-old Spanish-English bilinguals. The children were asked to describe a picture after having heard an adult describe a different picture. The researchers were also interested in a possible lexical boost effect[1] that word repetition – via translation equivalents – might have upon the priming effects. They found bi-directional, from L1 to L2 as well as from L2 to L1, and within languages priming effects. Importantly, the within-language effects were greater than the between languages effects. However, their study did not find a lexical boost effect. The authors point out that the absence of a lexical boost effect may be related to the fact that they were working with balanced bilingual children. That is, even if in adults an early stage of acquisition entails lexically dependent representations, thus creating the lexical boost effect, this may not be the case for children.

In the first study focused on cross-linguistic priming effects during bilingual language comprehension rather than production, Weber and Indefrey (2009) found priming effects during the comprehension of the passive voice by German-English late-acquisition bilinguals when prime and target sentences shared the same main verb. Employing an fMRI technique, they found decreases in brain activation (in the left inferior frontal gyrus, left middle temporal gyrus, and left precentral gyrus) as a result of cross-linguistic priming. They interpreted the results as indicative of an interaction between the syntactic systems of participants' L1 and L2.

The fact that Weber and Indefrey (2009) experimental design only included prime and target sentences with the same main verb refrains them from addressing an important issue about the very nature of the priming effects found: were they abstract or lexically-mediated? Abstract priming effects can only be attested when prime and target sentences share a syntactic structure. In the case of cross-linguistic studies, prime and target sentences must not include translation equivalents.

Wei and colleagues (2019) addressed this issue in two self-paced reading experiments. Different from Weber and Indefrey (2009), they were interested in within-language L2 priming. The study investigated the persistence of priming effects during the comprehension of English reduced relative clause sentences by adult Chinese-speaking learners of English. While in experiment 1 target and prime sentences shared the same main verb, in experiment 2 verbs were not repeated. The two main findings were that (1) priming was found even when prime and target sentences had until 2 filler sentences between them, and (2) priming effects also occurred in the absence of lexical repetition. That is, they were able to find persistent abstract priming effects.

A scenario in which abstract within-language L2 priming is found while abstract between-language L2 priming is not may suggest that L1 and L2 representations are not shared from the start. It is safe to assume that English learners from Wei et al's (2019) study had already built an abstract, that is, not lexically mediated, representation of the reduced relative structure in their L2. What we cannot know from their study is whether this L2 representation has any connections with their L1 representation of that same structure. One way to elucidate this issue is to manipulate the languages of prime and target sentences.

Working with the same language combination of the present study, Felicio (2018) investigated cross-linguistic priming effects in a population of Brazilian Portuguese-English bilinguals by means of a self-paced reading task. She found priming effects, indexed by shorter reaction times, only in one experimental condition. Participants only benefited from syntactic priming effects when prime and target sentence shared the same structure (the passive voice) as well as the same verb (via translation equivalents). Importantly, the author acknowledges that the lack of a between group analysis based on participants' L2 proficiency prevented her study from addressing issues regarding L2 syntactic development.

Finally, Muylle *et al.* (2020) used an artificial language (AL) learning paradigm to investigate between language structural priming effects during the early phases of L2 learning. The AL allowed both SVO (subject-verb-object) and SOV (subject-object-verb) word orders. Dutch, participants' native language, only allows for the SVO order. Results showed evidence for within-language (AL-AL) and between-language (AL-Dutch) priming effects with both word order configurations (for different results see Muylle *et al.,* 2021). The next subsection will present models of bilingual syntactic representation.

2.1 Two models of shared bilingual syntactic representation

The occurrence of structural priming effects between languages is in line with two important models of shared bilingual syntactic representation. The first of those models was proposed by Hartsuiker, Pickering, and Veltkamp in 2004. They propose that the bilingual representational system consists of an integrated network in which L1 and L2 lexical entries can be connected to the same combinatorial nodes. In this model, cross-linguistic structural priming effects are explained as the result of a mechanism of residual activation. In other words, assuming that nodes' activation threshold is lower when traces of residual activation remain in the network, the processing of a recently experienced structure would be facilitated by the processing of the same structure shortly before. In a shared network, priming effects would happen regardless of language: processing the passive voice in one language would facilitate the processing of the passive voice in another language.

Years later, in 2018, Bernolet, and Hartsuiker proposed a model focused on late bilinguals and on the issue of how they develop their L2 syntactic representations. While the former lexical-syntactic model for bilingual sentence

production proposed by Hartsuiker and colleagues (2004) deals with a stage in which L1 and L2 syntactic systems are totally shared, Bernolet and Harstuiker (2018) model tries to explain how learners get there.

Bernolet and Hartsuiker (2018) propose that, at the early stages of L2 learning, new L2 structures are not mapped into the existing L1 nodes. Instead, learners begin forming item-specific representations for L2 syntactic structures only after some exposure to the L2. As learning continues, a process of abstraction transforms these item-specific representations into proper syntactic nodes. That is, nodes go from representing a particular verb in a particular structure to representing only the structure. After that, an additional language node is formed, and all the abstract L2 syntactic representations are collapsed into the L1 nodes.

Importantly, the model makes some predictions regarding how cross-linguistic syntactic priming effects may be predicted by both L2 proficiency and translation between prime and target. If the stages proposed are indeed accurate, low proficient L2 speakers should show greater effects in the presence of translation equivalents since at early stages the syntactic representations are only item-specific. Differently, abstract priming effects should only appear at later stages, that is, only highly proficient L2 users should benefit from the structural repetition in the absence of translation equivalents.

The present study aimed at testing Bernolet and Harstuiker's (2018) predictions with a less studied population: late bilinguals of BP-EN. Doing so, the following research questions (RQ) were pursued:

- RQ1) Do reading times of late BP-EN bilinguals show cross-linguistic syntactic priming effects (from BP to EN) during the comprehension of the passive voice?
- RQ2) Does L2 proficiency predict cross-linguistic syntactic priming effects?
- RQ3) Is there an interaction between syntactic priming effects, lexical repetition (via translation equivalents), and L2 proficiency?

3. Method

3.1 Participants

Participants were 35 BP-EN late bilinguals (21 females) with ages ranging from 19 to 48 years (M=30, SD=6). The choice for this population was not made lightly. The reason behind our choice was threefold. First, due to the status of English as an international language, it is currently the most common second language in the world. Secondly, in Brazil, English and Spanish are the most studied foreign languages (Mello & Silva, 2013). Finally, various studies have already studied bilingual language processing with English as participants' L2 so our results will add to this literature with data from bilinguals with a less studied L1, Brazilian Portuguese.

Overall, participants started learning English at around 11 years of age (*M*=11, *SD*=7). Regarding their education, all participants had finished high school. The majority of the participants (52%) were either pursuing or already held a graduate degree and/or PhDs. Twelve participants (34%) reported having finished an undergraduate program, while five (14%) were still taking classes. The abundance of highly educated participants was not surprising, but it should not be left unnoticed since this appears to be a common trend in psychological sciences (Henrich et al., 2010; Henrich, 2020). Perhaps following the same trend, 29 participants (82%) reported having attended an English course.

Given that in both BP and EN the passive voice tends to be more frequent in writing than in spoken language, knowing participants' reading and writing habits may be informative. Reading in English appears to be a common activity for this study's sample since 82% of the participants reported reading fiction books, articles and general English content online (*e.g.,* posts on Reddit) regularly. Regarding their writing habits, 68% of the participants reported to write e-mails, reports, and academic assignments in English. From this, we assume that participants have had some experience with the passive voice in English. This information should be considered since priming effects are sensitive to the frequency of the structure being studied (Jaeger & Snider, 2013).

Participants were instructed to partake in two of DIALANG's tests: vocabulary and structure. After having done that, they went back to the study website and reported their results. DIALANG provides scores in accordance with the Common European Framework of Reference (CEFR). Table 1 shows participants' proficiency levels:

Table 1: *Participants' proficiency levels*

CEFR BROAD LEVEL	CEFR LEVEL	PARTICIPANTS
Proficient user	C2	6
	C1	13
Independent user	B2	11
	B1	5

The small number of participants at levels B1 and C2 lead us to broaden the initial grouping strategy: instead of working with four levels of proficiency we decided to work with two. That is, proficiency was defined as a factor with two levels. For the sake of clarity, from now on we will refer to proficient users as advanced and independent users as intermediate.

3.2 Experimental design

The two within-subjects factors investigated in the study were prime type and lexical repetition via translation equivalents. The first pair of experimental and control conditions manipulated the structural repetition between prime

and target sentences. In the experimental condition 1 (CE1), prime and target sentences were always in the passive voice and shared the same main verb. In the control condition 1 (CC1), prime sentences were in the active voice while target sentences were in the passive; the same main verb was used. This particular arrangement of conditions allowed us to tackle research question 1. Importantly, in a priming study the main concern of the analysis is the target sentence. That is, we compared the reaction time measures of the target sentences in both CE1 and CC1.

The second within-subject factor was lexical repetition. In the experimental condition 2 (CE2), prime and target sentences shared the passive structure but did not share the same main verb. In the control condition 2 (CC2), sentences did not share a syntactic structure, nor the main verb. Thus, if the target sentence of CE2 shows priming effects when compared to the target sentence of CC2, we will have found cross-linguistic priming effects in the absence of lexical repetition. That is, this manipulation allowed us to answer research question 2. This is of great significance because it provides evidence for a fully shared and abstract bilingual syntax.

The experiment contained a total of 240 experimental sentences, with 80 target sentences in English and 160 prime sentences in Brazilian-Portuguese. All target sentences were seven words long. An experimental block consisted of two prime sentences, one target sentence, and two to four filler sentences. The option for the use of two prime sentences was based on Weber and Indrefey (2009) and Thothathiri and Snedeker (2008), among other studies, and on the fact that the experimental literature shows that priming effects during comprehension may be harder to find than during production since in production priming studies require comprehension at the prime and production at the target thus possibly leading to a deeper processing demand. Thus, by adding two prime sentences we expected to increase the likelihood of priming effects to occur.

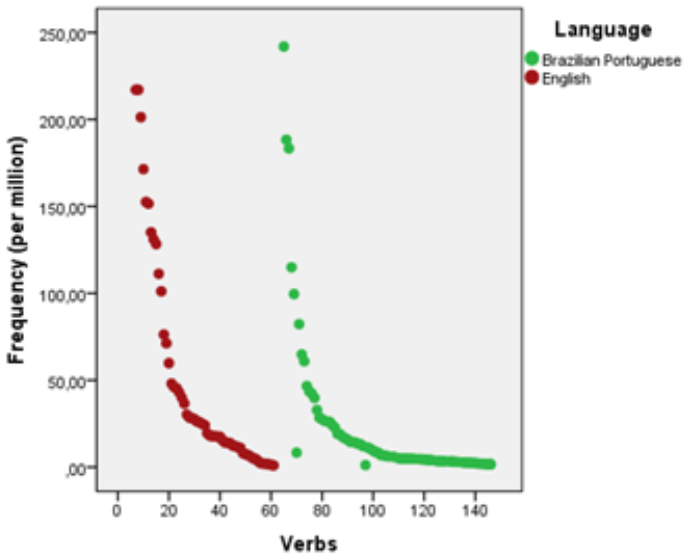
All sentences were counterbalanced for animacy. This decision was made based on previous research that pointed to the existence of semantic constraints on the passive voice (c.f. Ambridge & Bidgood, 2016; Aryawibawa & Ambridge, 2018; Bidgood et al, 2020). Among the possible semantic constrains great attention has been paid to issues related to animacy. For instance, would it be harder to process a passive sentence in which both agent and patient are not animated (*e.g.*, The flower was watered by the rain) when compared to the processing of passive sentence with an animated agent and a not animated patient (*e.g.,* The flower was watered by the man)? If a semantic constraint of animacy is indeed psychologically real, the answer to this question would be positive. Since the present study did not aim at addressing whether passive constructions are entirely syntactic or semantically structured, we decided to counterbalance our sentences for animacy. That is, experimental and control condition were made to have equal amounts of animacy features. The four possible combinations are (1) + animacy agents and – animacy patients, (2) - animacy agents and + animacy

patients, (3) + animacy agents and patients and (4) – animacy agents and patients. Examples of each sentence are given below:

(1) The room was illuminated by the lady.
(2) Our father was surprised by the noise.
(3) The author was published by her agent.
(4) The car was constructed by the machines.

After having done the animacy control, we also controlled the main verb of each sentence (prime and target) for frequency effects. Even tough prime sentences would not be statistically analyzed, a possible interference that processing a more or less frequent prime word may have in the subsequent processing of a target word cannot be disregarded. So, using the normalized frequency measures taken from the Cambridge Learner Corpus and the Brazilian Portuguese Corpus (both available at SketchEngine) we made a cut at the 250 occurrences per million mark. That is to say that both BP and EN main verb have similar frequency as it can be seen in figure 1.

Figure 1: *Scatter plot of the verbs per frequency and language*



After rewriting the sentences which had verbs that did not make the frequency cut, we subjected all sentences to grammaticality judgment tests. Both BP and EN sentences were analyzed by native speakers as to determine whether they are acceptable. The sentences were divided in lists. Each list was graded by 6 to 15 people. The test consisted of a Likert scale adapted from De Jesus (2018) that showed the following options:

1 - Totally unnatural. No one would write this.
2 - Weird. Acceptable, but it could be better.

3 - Good, but it could be more natural.
4 - Very good and natural.

Tables 2 and 3 show examples of the sentences with the mean for their acceptability.

Table 2 and 3: *BP and EN sentences and their mean for the grammaticality judgment test*

Sentence	Mean
O atleta foi lançado pela cama elástica.	3
A árvore foi plantada pela sua avô.	4
A roseira foi quebrada pela chuva forte.	4

Sentence	Mean
The surfer was lifted by the wave.	3,5
The ball was thrown by the player.	4
The mother was surprised by her daughter.	4

Sentences with the mean acceptability grade of 2 and 1 were revised and went through a new acceptability test. Finally, a revision for typos was made and the final version of the sentences was ready. After having the final 240 experimental sentences, 240 filler sentences were selected from two of LabLing's earlier studies: De Jesus (2018) and Felício (2019). The filler sentences were intransitives, in both BP and EN, were also 7 words long, and have already gone through grammaticality judgment tests. Examples of experimental sentences are given in Table 4.

Table 4 : *Experimental and control conditions*

Condition	**Prime**	**Target**
Experimental Condition 1 (CE1)	*A faca foi lavada pela cozinheira chefe..* [The knife was washed by the main cook.]	The girl was washed by the water.
Control Condition 1 (CC1)	*A parada brusca jogou o passageiro longe.* [The sudden stop threw the passenger far.]	The ball was thrown by the player.
Experimental Condition 2 (CE2)	*O show foi visto pela criança animada.* [The show was watched by the excited child.]	The baby was fed by the lady.
Control Condition 2 (CC2)	*A brisa suave mecheu as folhas verdes.* [The soft breeze moved the green leaves.]	The piano was carried by the pianist.

3.3 Instruments

Three instruments were used in the present study: a biographical and language experience questionnaire, an English proficiency test, and a self-paced reading task.

3.3.1 The biographical and language experience questionnaire

Based on previous studies conducted in our lab, we adapted a two-section questionnaire. While the first section aimed at gathering participants' general information (*e.g.* age, sex, level of schooling), the second addressed issues regarding participants' L2 experience. Importantly, knowing that the syntactic structure of interest in the study tends to occur more frequently in written Portuguese (Teixeira, 2016), we also included questions regarding participants' reading and writing habits.

3.3.2 The proficiency test

The test selected to measure participants' L2 proficiency was the DIALANG (Alderson, 2005; Alderson & Huhta, 2005). It rates proficiency according to the Common European Framework of References for Languages (CEFRL). The choice for this particular proficiency test was threefold. First, DIALANG is an on-line diagnostic language assessment system designed so that students could take it without the presence of an instructor. Since the data collection was conducted remotely this feature was paramount to our choice. Second, DIALANG has specific tests for the skills of reading, listening, writing, vocabulary and structures. For the purpose of the present study, participants performed the placement and structures tests. The placement test establishes the level of difficulty of the later structure test. It consists of a list of words and non-words and participants should mark the ones that they consider to be real English words. At last, DIALANG has received positive critique regarding its efficiency (Kektsidou & Tsagari, 2019) and we judged it to be more thorough than other free proficiency measures.

Although simple, DIALANG's interface is user friendly, and participants were expected to be able to navigate the website without major setbacks. However, since there are many options of tests to take within DIALANG, guidelines were included as shown in Figure 2. Figure 3 shows an example of a question from the structures test.

Figure 2: *Guidelines for the proficiency exam*

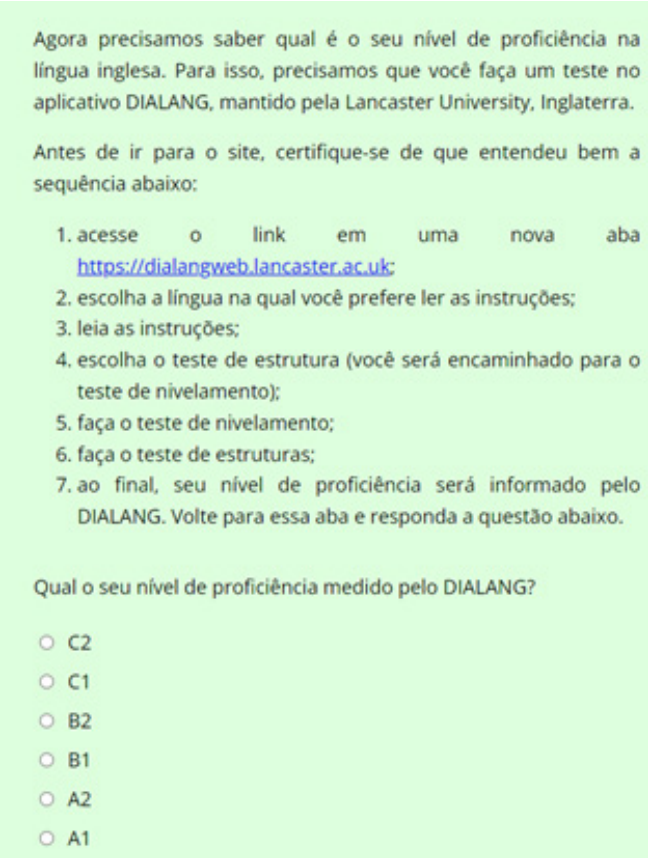
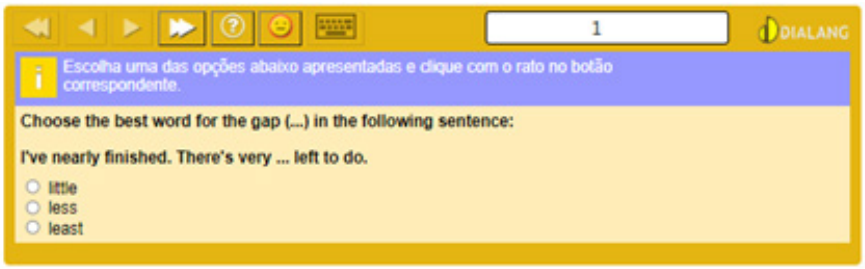


Figure 3: *Example of a DIALANG question*



3.3.3 The self-paced reading task

We used a one-word moving-window self-paced reading task to investigate how processing the passive voice in BP would influence the subsequent processing of the passive voice in EN. Before each sentence, a fixation cross appeared for 1 second in the upper left area of the screen, the same place where the sentence would appear, so participants could fixate their eye gaze in the initial point of the upcoming sentence. The words were masked with hyphens (-) and to read them participants should press the spacebar. Once a new word was revealed the previous word was re-masked.

The words were presented in black font (Monospace, font size 22) on a light green background. One experimental trial consisted of two prime sentences, one

target sentence, and one to four filler sentences. The amount of filler sentences was not kept constant in an effort to make it harder for participants to detect a pattern. A block consisted of three trials. After each block participants answered a memory question by pressing S (for yes) or N (for no) on their keyboard. The memory questions always referred to a filler sentence and were counterbalanced for language. Examples of filler sentences and memory questions are provided below:

(5) The famous artist drank the cold water.
(6) Did the artist drink the cold water?
(7) A mulher sozinha viajou para a praia.
(8) A mulher sozinha viajou para a reunião?

The task was divided into two parts, each consisting of 40 trials. A 180ms pause was included between parts. The order of trial presentation was randomized for each participant. Two blocks of practice trials were included in the beginning of the experiment so participants could get familiar with the task.

3.3.4 Procedures

This study was carried out during the emergency period of the COVID-19 pandemic. Therefore, all data collection was conducted remotely. The experiment was programmed using the JsPsych library (De Leeuw, 2015). Data collection for the present study was only conducted after receiving the University ethics review board's permission. Participants used their own computers to access the study. A data collection session lasted from 40 to 70 minutes, and it was composed of four parts. The first part of the study consisted of reading and signing the consent form. After that, in part two, participants answered the biographical and language experience questionnaire. Part three consisted of performing the proficiency exam on the DIALANG website. Finally, part four consisted of the self-paced reading task aimed at assessing structural priming effects.

4. Results

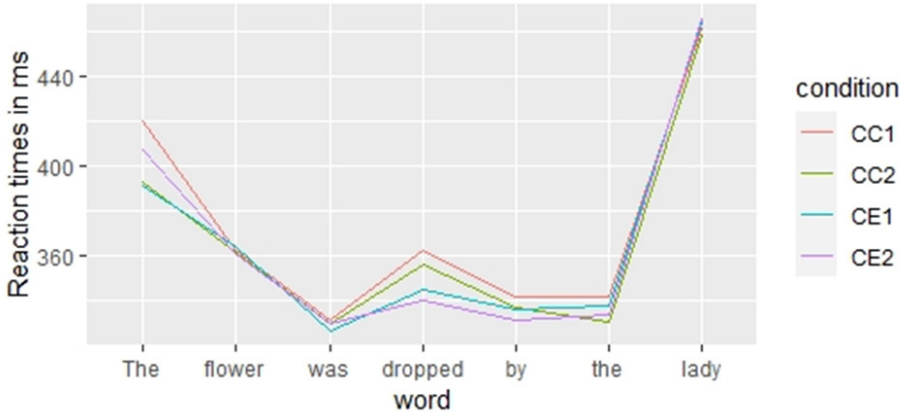
The main goal of the present study was to investigate the occurrence of cross-linguistic syntactic priming effects during the processing of the passive voice in English by BP-EN late bilinguals. The cross-linguistic priming effects that we were interested in were from L1 to L2. That is, we assessed the occurrence of priming effects by observing whether a participant processed an English passive target sentence faster after having been exposed to a Brazilian-Portuguese passive prime sentence when compared to a control sentence. More than that, we were also interested in the role played by translation equivalents upon the priming effects. The issue of how proficiency interacted with priming effects and with lexical repetition (via translation equivalents) was also investigated.

All data were analyzed using R (version 4.1.2; R core team, 2019) with the R packages lme4 (Bates et al., 2015) and jsPlot (Lüdecke, 2021). To test the hypothesis that reading times are faster for the target sentences in the experimental compared to the control conditions, we first conducted a descriptive reading time analysis on the reading times of word 4. The descriptive analysis on word 4 showed that, as expected, participants read the experimental conditions (CE1 and CE2) faster than the control conditions (CC1 and CC2) (see table 4 for means and standard deviations in which condition). Figure 4 shows the mean reaction times per word and per condition.

Table 4: *Means and standard deviations from each conditions*

Condition	Mean	SD
Experimental Condition 1 (CE1)	345.53	162.14
Control Condition 1 (CC1)	363.37	186.38
Experimental Condition 2 (CE2)	340.04	165.23
Control Condition 2 (CC2)	356.76	178.35

Figure 4: *Reaction times per word and per condition*



For the inferential analysis, mixed-effects modeling was used to assess if RTs significantly decreased as a function of prime type and/or verb repetition. Condition and proficiency were included as fixed factors while participants and items were random factors. Since we also wanted to test whether verb repetition would enhance priming effects differently depending on proficiency, interaction terms for condition and proficiency were also included.

The results showed a significant main effect of condition for both CE1 (β: -28.92, $p < .01$) and CE2 (β: -29.874, $p < .01$). Contrary to expectations, there was no significant main effect for proficiency nor for the interaction between fixed factors (namely, proficiency and condition). Interestingly enough, a comparison between marginal and conditional R^2 values indicates that the full model (*i.e.*, the model with both fixed and random factors) explained better the variability than the model with only fixed factors (see Figure 5).

Figure 5: *Summary of the statistical model for word four (the main verb)*

		rt	
Predictors	*Estimates*	*CI*	*p*
(Intercept)	377.93	297.10 – 458.76	**<0.001**
condition [CC1]	0.80	-19.63 – 21.23	0.939
condition [CE1]	-28.92	-50.25 – -7.58	**0.008**
condition [CE2]	-29.87	-51.41 – -8.34	**0.007**
proficiency [2]	-36.93	-146.60 – 72.73	0.509
condition [CC1] * proficiency [2]	9.43	-18.32 – 37.19	0.505
condition [CE1] * proficiency [2]	27.02	-2.03 – 56.08	0.068
condition [CE2] * proficiency [2]	22.76	-6.68 – 52.20	0.130
Random Effects			
σ^2	17870.54		
$\tau_{00\ participant}$	28900.36		
$\tau_{11\ participant.item}$	0.29		
$\rho_{01\ participant}$	-0.32		
ICC	0.62		
$N_{\ participant}$	35		
Observations	2937		
Marginal R^2 / Conditional R^2	0.005 / 0.620		

A model was also built to look for priming effects during the processing of word 5 (the by preposition). However, no significant results were found on word 5 (all $p > 0.5$). See figure 6 for the full model.

Figure 6: *Summary of the statistical model for word five (the by preposition)*

	rt		
Predictors	*Estimates*	*CI*	*p*
(Intercept)	370.17	322.50 – 417.84	**<0.001**
condition [CC1]	-1.57	-17.88 – 14.74	0.850
condition [CE1]	1.18	-15.31 – 17.66	0.889
condition [CE2]	-8.72	-25.35 – 7.91	0.304
proficiency [2]	-46.61	-111.25 – 18.03	0.158
condition [CC1] * proficiency [2]	8.49	-13.68 – 30.66	0.453
condition [CE1] * proficiency [2]	-6.18	-28.59 – 16.24	0.589
condition [CE2] * proficiency [2]	3.28	-19.37 – 25.94	0.776
Random Effects			
σ^2	11834.63		
$\tau_{00\ participant}$	10737.89		
$\tau_{11\ participant.item}$	0.02		
$\rho_{01\ participant}$	-0.84		
ICC	0.48		
$N_{\ participant}$	35		
Observations	2945		
Marginal R^2 / Conditional R^2	0.023 / 0.488		

5. Discussion

The presence of cross-linguistic priming effects from L1 to L2 during the comprehension of the passive voice by BP-EN late bilinguals is the main finding of the present study. Participants were consistently faster to process the main verb of the target sentences in English after having just processed the prime sentences in Portuguese in both experimental conditions. Differently than expected, all participants – regardless of proficiency level – showed both lexically dependent and abstract priming effects.

To reiterate, the experiment consisted of two experimental and two control conditions. In experimental condition 1 (CE1), prime and target sentences shared the same syntactic structure and translation equivalents were included (e.g., *visto* – seen). In control condition 1 (CC1), the same verb was repeated between prime and target sentences, but the syntactic structure was not the same (e.g., *viu* [saw] – seen). In experimental condition 2 (CE2), prime and target sentences shared the same syntactic structure, but no translation equivalents were included (e.g., *visto* [seen] – hugged). Finally, in control condition 2 (CC2), prime and target

syntactic structures differed and no translation equivalents were included (*e.g. comeu* [ate] – kissed).

Structural priming effects can be explained as the results of the residual activation left by the processing of a prime sentence (Tooley, 2020). The fact that in the present study, the processing of a BP passive sentence facilitated the later processing of an EN passive sentence can only be conceived in a scenario in which BP and EN syntactic representations are shared. Importantly, that is not to say that structural priming can only be explained as the result of residual activation. In fact, much attention is being drawn to the possibility that an implicit learning mechanism might be responsible for priming effects. The present study, however, was not aimed at advocating between the residual activation and the implicit learning accounts.

Figure 7 illustrates what may have happened during the experiment reported here.

Figure 7: *Bilingual representational network during an experimental trial*

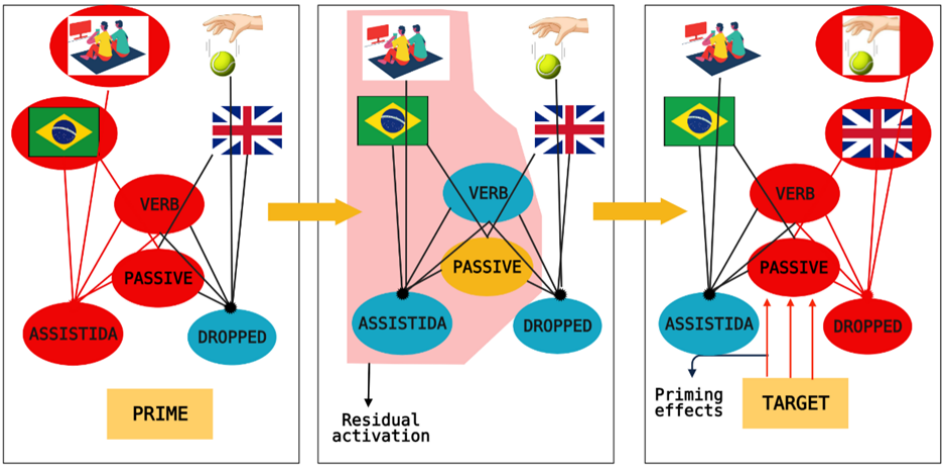


Figure 4 represents a mechanistic account of cross-linguistic structural priming effects based on Hartsuiker, Pickering and Veltkamp's (2004) proposal. The following representational nodes are depicted: two lemma nodes (*assistida* [watched] and dropped), one category node (verb), one combinatorial node (passive), two language nodes (Brazilian-Portuguese and English), and two conceptual nodes (to watch and to drop).

From left to right, the first image accounts for the processing of the main verb of a BP prime sentence in experimental condition 2 (CE2). For example, when a participant processed the verb *assistida* (watched) in the prime sentence *A novela foi assistida pela moça loira* (The soap opera was watched by the blond lady) the following nodes were activated: the lemma node of *assistida* (watched), the passive voice combinatorial node, the verb categorical node, the BP language node, and the conceptual node. Node activation is represented by the color red. The activation is spread through the links between nodes that are also colored in red when recruited.

Note that the passive node is shared by both language nodes since the passive voice exists in both BP and EN and share the same word order. In other words, the passive node is not language specific. Following Bernolet and Hartsuiker's (2018) trajectory model, the sharing of combinatorial nodes only happens at the final stage of L2 syntactic development. Thus, the representational network depicted in figure 3 might not be suitable for the representation of earlier stages of L2 acquisition.

The central image shows the state of the representational network right after the processing of the prime sentence. The residual activation left in the nodes is pivotal to the occurrence of the priming effects represented in the last image. As explained by Muylle, Bernolet and Hartsuiker (2020) the residual activation retained by the nodes makes subsequent activation easier: given a residually activated and a resting state node, the residually activated node will reach the activation threshold faster thus giving rise to the priming effects.

The last image represents the state of the network during the processing of the main verb of an EN target sentence in CE2. Since both prime and target sentences share the same syntactic structure, the passive node had to be activated twice. Crucially, the second time around, the activation happened faster due to the residual activation left in the network. The red arrows symbolize the structural priming effects.

The fact that priming effects were found in both experimental conditions regardless of proficiency level is also an important finding of the present study. According to Bernolet and Hartsuiker's (2018) model, L2 syntactic representations go from lexically dependent to fully abstract. In other words, at lower levels of proficiency L2 learners are expected to establish lexically bounded syntactic representations. That is, once they encounter a new L2 verb occurring in a given syntactic structure they would develop a new representation node for that particular verb in that particular syntactic structure. At this stage, syntactic representations are neither abstract nor non-language specific. Regarding cross-linguistic priming effects, low proficient L2 users would only be susceptible to them when prime and target sentences share the same main verb. In the case of the present study, participants with a lower level of proficiency were expected to only show cross-linguistic priming effects at CE1. Admittedly, that was not the case.

Two possible explanations for the presence of abstract cross-linguistic priming effects regardless of proficiency are proposed. At first, the small and uneven number of participants at each proficiency level may have hindered the model's ability to find a significant interaction between priming effects and proficiency. Conversely, assuming that sample size was not the issue, it is also possible that at the intermediate level of proficiency, L2 users have already reached the stage in which syntactic nodes are abstract and shared between languages. In other words, they may have already reached the last stage of the bilingual syntax and, as such, the representations and processing procedures that they go through are the same that advanced L2 users rely upon.

Of keen importance to the results found here is the fact that, unlike other studies that dealt with cross-linguistic priming effects during comprehension (*e.g.* Felicio, 2018), the experimental design implemented included a 2:1 prime and target proportion. That is, participants processed the EN target sentence after having processed two BP prime sentences. Taking a closer look at the methodological procedures of priming studies such as Bock (1986) one interesting characteristic came to light. Even though the authors reported having used only one prime, participants seem to have at least two instances of contact with each the syntactic structure: one when reading the sentence and another when repeating it. What if having two instances of contact with each prime increased its depth of processing? Craik and Lockhart (1972) argued that a greater depth of processing implies "a greater degree of semantic or cognitive analysis" (p. 675). Perhaps having processed the passive structure twice in the two prime sentences, participants were more likely to retain some of its aspects in memory thus enabling the occurrence of priming effects. Of course, the relation between double primes, depth of processing, and priming effects during comprehension is only a possibility. However, considering the findings reported here, further research may benefit from investigating this possibility.

Finally, a surprising finding should be addressed. Participants spent more time processing the main verb of CC1 than they did in any other condition. That is surprising since CC2 is the one in which neither syntactic structure nor lexical content is repeated between prime and target sentences; thus, it was expected that the higher RTs measures found would be on CC2. However, repeating the same verb (e.g., *to kiss*) but not the same syntactic structure (*beijou* [kissed] – was kissed) taxed participants' performance more than having no repetition at all (*comeu* [ate] – was hugged). This finding warrants further research, but it is possible that an inhibitory process was triggered: having processed a verb in a determined syntactic structure, participants might have to inhibit the following processing of the same verb in the same syntactic structure. In other words, the residual activation left on the passive node had to be suppressed thus giving rise to some processing load.

6. Conclusion

Based on the results of the experiment carried out the following proposal is put forward: BP-EN late bilinguals with intermediate and advanced levels of proficiency have already reached a developmental stage in which the passive voice node is fully shared between their two languages. That is, intermediate and advanced L2 speakers of English, whose L1 is Brazilian Portuguese seem, to have only one shared syntactic representation for the passive voice. Importantly, the use of two prime sentences may have led to a deep processing of the structure thus allowing the occurrence of the observed priming effects.

In other words, the results of the present study indicated that late BP-EN bilinguals have a shared syntactic system for at least some of the syntactic

structures present in both languages. Besides that, when considering bilinguals with intermediate and advanced levels of proficiency, their susceptibility to both lexically dependent and abstract cross-linguistic priming effects seems to be the same. That is, proficiency did not interact with the observed priming effects. Objectively, the following findings are put forward:

1. BP-EN late bilinguals are susceptible to cross-linguistic syntactic priming effects from BP to EN during the comprehension of the passive voice when prime and target sentences share the same main verb.

2. BP-EN late bilinguals are susceptible to cross-linguistic syntactic priming effects from BP to EN during the comprehension of the passive voice even in the absence of translation equivalents. In other words, they are susceptible to abstract cross-linguistic syntactic priming effects.

3. When dealing with intermediate and advanced L2 speakers, there is no interaction between proficiency and the occurrence of cross-linguistic syntactic priming effects from BP to EN during the comprehension of the passive voice.

Although having fulfilled its objectives, the study reported here has some limitations. Perhaps the most important one is that it was not a longitudinal study. The fact that proficiency was not a within-subject factor may have contributed to the unexpected lack of interaction between proficiency and cross-linguistic priming effects. More than that, the comparison of r square values indicated that the variability found in the model was deeply related to its random factors, that is, participants and items. Further research on L2 syntactic development may consider implementing a longitudinal study.

The small number of participants at each proficiency level may also be considered a limitation. Jiang (2012) explains that there is no ideal number of participants for an RT study. Instead, he posits that an informed decision should be made based on features of each particular experimental design. For instance, having participant-related independent variables with different levels may entail the need for a larger sample size. As mentioned in the method section, due to the small number of participants we had to abandon the initial idea of having proficiency as an independent variable with four layers. However, even after having done so, we still worked with a two-layered independent variable of proficiency that perhaps called for more participants.

Another consideration pointed out by Jiang (2012) regarding the number of participants refers to the specific effect under investigation. Perhaps, the nuanced nature of cross-linguistic priming effects during comprehension would be more thoroughly observed with a larger sample. That is, the behavioral manifestation of the difference between abstract cross-linguistic priming effects and lexically bounded cross-linguistic priming effects may warrant more observations.

Although speculative, it is also possible that only more fine-grained methods would have been able to detect a difference that does not translate to behavioral measures such as RTs. In light of that, further research may consider replicating the present study with hemodynamic and/or electrophysiological measures of brain activity.

Finally, including participants with even lower levels of proficiency would be of great benefit to future studies. In fact, most of the participants of the present study were at neighboring levels of proficiency (namely, B2 and C1). This alone may indicate that the results found here are not able to produce a comprehensive picture of L2 syntactic representation at different proficiency levels thus creating the need for further scrutiny.

Note

1. The term lexical boost is used in the priming literature when referring to an enhancement in the robustness of a priming effect due to the presence of shared lexical content between prime and target sentences (Mahowald et al., 2016; Scheepers et al., 2017; Tooley et al., 2018).

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