Neuropsychologia 97 (2017) 112–139

Contents lists available at ScienceDirect

Neuropsychologia

journal homepage: www.elsevier.com/locate/neuropsychologia

Switching direction affects switching costs: Behavioral, ERP and time-frequency analyses of intra-sentential codeswitching

Kaitlyn A. Litcofsky*, Janet G. Van Hell

Pennsylvania State University, USA

ARTICLE INFO

Keywords:
Intra-sentential codeswitching
Bilingualism
Event-related potentials
Time-frequency analysis

ABSTRACT

Bilinguals have the unique ability to produce utterances that switch between languages. Most language switching research has focused on isolated, unrelated items, which emphasizes separation of the languages. Fewer studies examined the cognitive and neural mechanisms of switching languages in natural discourse. The present study examined the effect of codeswitching direction on the comprehension of intra-sentential codeswitching in Spanish-English bilinguals, using self-paced reading behavioral measurements (Experiment 1) and electroencephalography (EEG) measurements (Experiment 2), analyzed via both event-related potentials (ERPs) and time-frequency analysis (TFR). Reading times showed a significant switching cost for codeswitched sentences in both codeswitching directions, though switching costs were somewhat higher into the dominant language than into the weaker language. ERPs showed that codeswitched as compared to non-switched words elicited a late positivity, but only when switching from the dominant into the weaker language, not in the reverse direction. TFRs showed complementary and converging results: switches into the weaker language resulted in a power decrease in lower beta band while switches into the dominant language resulted in a power increase in theta band. These multi-method findings provide novel insights into neurocognitive resources engaged in the comprehension of intra-sentential codeswitches related to sentence-level restructuring processes to activate and access the weaker language.

1. Introduction

Over half of the world's speakers are bilingual (Marian and Shook, 2012). A unique feature of bilingual speech is that bilinguals often produce utterances that switch between languages, such as "I ate *huevos para el desayuno* [eggs for breakfast]". This *codeswitching* has been shown to occur in various natural situations (e.g., Clyne, 1967; Grosjean, 2001; Muysken, 2000). The phenomenon indicates that during conversation bilinguals have both languages active to some extent and are able to dynamically adjust relative levels of activation of the two languages to flexibly use either or both languages. While the question of language planning in codeswitching and which switch points are most common or expected is of much interest (see e.g., Fairchild and Van Hell, 2017; Jake et al., 2002; Pfaff, 1979; Poplack, 1980; Wei and Milroy, 1995; Valdés Kroff et al., 2016), it is important to note that codeswitches occur in conversation and must be successfully comprehended by the interlocutor. This comprehension of these intra-sentential codeswitches is the focus of the current study (for studies on inter-sentential switches, see, e.g., Gullifer et al., 2013; Ibáñez et al., 2010; Tarlowski et al., 2013).

The large majority of studies in the cognitive and neurocognitive literature examining switching between languages have actually focused on the processing of a series of single, unrelated items (e.g., words, numbers, or pictures) in language switching paradigms. While these tasks are devoid of a rich linguistic context, these studies provide an experimentally-controlled foundation that may help better understand the mechanisms underlying the processing of more naturalistic codeswitching. Behavioral, event-related potential (ERP), and functional magnetic resonance imaging (fMRI) studies converge on the finding that switches, as compared to non-switches, incur a processing cost and have sought to understand the mechanisms recruited during switching. We will first briefly summarize the findings from these studies and then turn to studies of the comprehension of codeswitches in meaningful utterances.

1.1. Switching of single, isolated items

In the language switching paradigm, participants are either presented with items that switch between languages (in comprehension tasks) or must change the language of their response across trials (in

* Correspondence to: Department of Psychology, Pennsylvania State University, 006 Moore Building, University Park, PA 16802, USA.
E-mail address: kal378@psu.edu (K.A. Litcofsky).

http://dx.doi.org/10.1016/j.neuropsychologia.2017.02.002
Received 28 July 2016; Received in revised form 29 January 2017; Accepted 1 February 2017
Available online 03 February 2017
0028-3932/

production tasks). For both, switch trials are compared to non-switch trials (for a recent review, see Bobb and Wodniecka (2013)). In production, the dominant finding (e.g., Meuter and Allport, 1999) has been an asymmetrical switching cost, in which it is more costly to switch into the first language (L1) than into the second language (L2). This pattern is found for the naming of digits (e.g., Jackson et al., 2001; Meuter and Allport, 1999), pictures (e.g. Costa and Santesteban, 2004; Declerck et al., 2012), as well as for reading words aloud (e.g. Filippi et al., 2014; Macizo et al., 2012; Reynolds et al., 2016; Slevc et al., 2016). The most prominent explanation for these findings posits inhibitory control of the non-target language (Green, 1998; though alternative accounts have been proposed, e.g., Philipp et al., 2007; Verhoef et al., 2009). That is, to successfully name an item in the weaker language, a bilingual must strongly inhibit their more dominant language. When they then switch into the dominant language, that inhibition must be released. In the reverse switching direction, from the dominant to the weaker language, successful item naming in the dominant language requires less inhibition of the relatively weaker language.

However, in studies of language switching in comprehension, the patterns of switching costs have been more varied, with larger costs often found into the L2 rather than the L1 (see Bobb and Wodniecka (2013)). One explanation for the asymmetrical switching costs in comprehension comes from the developmental variant of the Bilingual Interactive Model for word comprehension (BIA-d, Grainger et al., 2010; cf. BIA+; Dijkstra and Van Heuven, 2002). The model proposes that words in each of the bilinguals' two languages are connected to a language node (one for each language), which becomes active when a word in this language is encountered. Language nodes can also exert top-down control: when a language node is activated, words in that language will compete for selection and the language node inhibits words of the other language. The BIA-d model implements both endogenous control (via top-down activation or maintenance of top-down activation driven by expectancies regarding incoming information) and exogenous control (via bottom-up activation of language nodes via lexical representations). Switch costs in comprehension arise from the bottom-up activation of a given language node driven by the presentation of a word in that language, which also leads to the inhibition of words in the other language. To explain larger switching costs into L2 than into L1 during comprehension, the model emphasizes the notion of relative language proficiency, and assumes that L1 lexical representations have higher resting levels of activation than L2 lexical representations, which makes the language node receive stronger exogenous bottom-up activation from L1 words than from L2 words. Thus, when switching from L1 into L2, the stronger L1 activation creates more interference for the incoming L2 words and results in larger switching costs into the L2.

Regardless of the task modality, these single-item switching studies emphasize separation of a bilingual's languages. By utilizing a series of unrelated single words, digits, or pictures as stimuli, and inserting language switches across, but not within trials, participants are forced to categorize each trial separately as belonging to one or the other language. Studying isolated-item switching allows for the investigation of how bilinguals maintain control of their two languages, but does not represent language switching in a meaningful context where words from both languages are to be integrated to form a coherent message, as in codeswitching during natural conversation.

In contrast to the multitude of language switching studies, less psycholinguistic and neurocognitive research has focused on the processing of switching languages within the context of meaningful utterances, such as sentences (see Van Hell et al. (2015), for a review), and even fewer studies have examined neurocognitive processes associated with intra-sentential codeswitching (Moreno et al., 2002; Ng et al., 2014; Proverbio et al., 2004; Van der Meij et al., 2011). Next we will discuss switching in these more meaningful sentence contexts.

1.2. Switching within sentences: behavioral studies

In an effort to determine the cognitive processes associated with switching within meaningful sentences, recent studies used psycholinguistic methods to study intra-sentential codeswitching in two switching directions (Bultena et al., 2015a, 2015b; Dijkstra et al., 2015; Wang, 2015). For example, Wang (2015) asked English-Chinese bilinguals to perform a maze task (Forster et al., 2009) in which they had to choose one of two alternative words presented on the computer screen (e.g., “The .... rain/were but/fell clock/silently”) in order to move through the sentence (correct selection: “The rain fell silently”). Sentences were all in English (as were the choice-alternatives) with codeswitched sentences containing a single Chinese noun in subject or in object position (the choice-alternative was also a Chinese noun). To investigate the role of relative proficiency on the processing of the codeswitches, half the bilinguals were English-dominant, and half were Chinese-dominant. The English-dominant bilinguals showed a switch cost on the codeswitched Chinese word, as well as on the following word that switched back to English. The Chinese-dominant bilinguals showed faster processing times on the switched Chinese noun than on the non-switched English equivalent in the all-English sentence. The following word that switched back to English yielded a switching cost in the Chinese-dominant bilinguals. Wang interprets the switching costs on the English word following the single-noun switch to Chinese as an inhibitory effect associated with comprehending codeswitched sentences. As such cognitive costs were observed in both English-dominant and Chinese-dominant bilinguals, Wang concludes that cognitive efforts to inhibit the other language on the previous word (the codeswitched word) are not modulated by language proficiency. This inhibitory control explanation of the comprehension of intra-sentential codeswitching strongly resembles the inhibitory control account that dominates explanations of isolated-item language switching in production (see Bobb and Wodniecka (2013)).

The maze task used by Wang (2015) requires item-based selection of the correct word, and discarding and inhibiting the incorrect alternative, while incrementally building a sentence. This potentially invites stronger cognitive control processes than does more naturalistic reading. Dijkstra et al. (2015) studied codeswitching in Dutch-English bilinguals who read Dutch and English sentences presented word-by-word. The sentence-final word either switched to the other language or remained in the same language, and participants conducted a lexical decision task on these sentence-final target words. The Dutch-English bilinguals demonstrated a switching cost that was of similar magnitude when switching from L1 Dutch to L2 English as when switching from L2 English to L1 Dutch.

Wang (2015) and Dijkstra et al. (2015) studied switching costs associated with a lexical switch, i.e., a single word presented in a language different from the sentence. Bultena et al. (2015a, 2015b) studied codeswitching in sentences that fully switched into the other language. Such alternational switches better reflect naturally codeswitching in daily conversations (Milroy and Muysken, 1995; Poplack, 1980). Using a self-paced reading task (Bultena et al., 2015a), Dutch-English bilinguals read sentences that started in L1 Dutch and switched half way into L2 English, or vice versa, as well as single-language sentences. The self-paced reading times showed a switching cost for switching from L1 Dutch into L2 English, but not vice versa. Moreover, switching costs into L2 English were smaller as the bilinguals' L2 proficiency increased. A similar asymmetrical switching cost pattern was obtained in a shadowing task (Bultena et al., 2015b), in which Dutch-English bilinguals listened to codeswitched sentences that started in L1 Dutch and switched into L2 English, or vice versa, as well as single-language Dutch and English sentences. As soon as bilinguals heard the beginning of the sentence, they were asked to repeat (‘shadow’) what they heard as quickly and as accurately as possible. Shadowing latencies (i.e., the delay between word onset in the original recording and the participant's reproduction of the word)

showed that switching from L1 into L2 was more costly than switching from L2 into L1, thereby replicating the pattern observed in Bultena et al.'s (2015a) self-paced reading study. Both studies showed that switching to the weaker L2 is harder than switching to the dominant L1 (an asymmetry also observed by Wang (2015)), and Bultena et al. (2015a, 2015b) proposed that intra-sentential switching costs are driven by how quickly representations in a language can be activated. They claim that relative proficiency in the L1 and L2, rather than inhibitory control, underlie intra-sentential switching costs in comprehension. This finding is in line with the BIA-d's explanation of single-item language switching comprehension (Grainger et al., 2010).

Bultena et al. (2015a, 2015b) and Dijkstra et al. (2015) tested Dutch-English bilinguals who are not habitual codeswitchers, and this is presumably also true for the Chinese-English bilinguals tested by Wang (2015). In the present study we tested highly fluent bilingual speakers of Spanish and English who are habitual codeswitchers. In Experiment 1, the Spanish-English bilinguals completed a self-paced reading task and read sentences that fully switched to the other language, from Spanish to English or vice versa. This behavioral experiment extends the currently available evidence in intra-sentential codeswitching in two directions by studying habitual codeswitchers, a population whose neurocognitive mechanisms of language control may be qualitatively different from non-habitual codeswitchers, as recently proposed by Green (2011) and Green and Wei (2014). The self-paced reading times collected in Experiment 1 will also provide processing time information (i.e., predicted switching cost: longer processing times of switched words relative to non-switched words) against which EEG/ERP effects associated with intra-sentential codeswitching (Experiment 2) can be interpreted. For example, longer RTs to a codeswitched word relative to a non-switched control word validates that an increased ERP amplitude to a codeswitched word signifies a cost. Using EEG/ERP, Experiment 2 records the brain's electrical activity while comprehending intra-sentential codeswitches, and seeks to identify the neurocognitive processes involved in codeswitching from the dominant to the non-dominant language and vice versa.

1.3. Switching within sentences: electrophysiological studies

As will become apparent from the literature review in this section, electrophysiological studies of intra-sentential codeswitching have focused only on single-item lexical switches, not full alternational switches, and have not systematically compared switching in both directions. In the present study, we examine the processing of naturalistic alternational codeswitches and directly compare how switching direction affects processing.

Moreno et al. (2002) studied whether codeswitches are processed similarly to within-language lexical switches in sentences. Using ERPs, they examined balanced English-Spanish bilinguals reading sentences in L1 English that ended in either a codeswitch into L2 (e.g., “Each night the campers built a *fuego* [fire]”.), a same-language lexical switch (e.g., “Each night the campers built a *blaze*“.), or no switch (e.g., “Each night the campers built a *fire*”.). Lexical switches, as compared to no-switches, showed a classic N400, whereas codeswitches resulted in a negativity more similar in scalp topography to a left anterior negativity (LAN), which has been associated with working memory demands (King and Kutas, 1995), or morphosyntactic processing (Gunter et al., 1997). Codeswitches also resulted in a late positive component (LPC), which they interpreted as a P300 (Donchin, 1981), where the codeswitch represents an unexpected change in form that requires additional processing for context updating. Based on the different ERP responses to the different switch types, Moreno et al. concluded that codeswitches are processed differently from lexical switches, and their processing is external to lexico-semantic mechanisms.

Building upon Moreno et al. (2002), Van der Meij et al. (2011) examined how proficiency modulates the processing of intra-sentential single-word switches. Higher- and lower-proficiency Spanish-English bilinguals read sentences in L2 English that contained a sentence-medial adjective that could either be in L1 Spanish (switch) or in L2 English (non-switch). While the codeswitched words in Moreno et al. (2002) could be cognates, which may alter the relative activation of the two languages at the point of the codeswitch (for reviews, see e.g., Dijkstra, 2005; Van Hell and Tanner, 2012), Van der Meij et al. (2011) ensured that the codeswitched words were not cognates. In both proficiency groups, codeswitched words elicited an N400 and LPC response, though both effects were larger in the higher proficiency bilinguals. The N400 in the high proficiency group extended to left anterior sites, similar to the LAN that was found in Moreno et al. (2002). Overall, the Van der Meij et al. study found that bilinguals of both low and high proficiency showed processing costs related to lexico-semantic processing and sentence-level restructuring (Kolk and Chwilla, 2007; Van Petten and Luka, 2012), and higher proficiency bilinguals showed more robust effects, either because they processed the sentences more deeply or recruited more resources to process the codeswitch.

A recent study by Ng et al. (2014) examined the processing of codeswitches in a larger discourse context. Balanced Spanish-English bilinguals read short stories in English that either contained codeswitched words in Spanish or remained entirely in English. Similar to previous findings, codeswitched words elicited a biphasic LAN and LPC.

These studies suggest that intra-sentential codeswitches incur processing costs (in terms of increased ERP components) that are distinct from within-language lexical switches, are modulated by L2 proficiency, and may involve lexico-semantic and sentence-level restructuring mechanisms based on their biphasic ERP response. Of note, no study reports N2 ERP effects (a component associated with response suppression and conflict monitoring, Folstein and Van Petten, 2008) as found for the language switching studies (Jackson et al., 2001), suggesting that the processing of language switches in a meaningful context (i.e., sentences) relies on comprehending the sentence to extract meaning and is fundamentally different from the processing of language switches in a series of isolated, unrelated items where language separation is emphasized.

However, these intra-sentential codeswitching studies examined codeswitching in only one switching direction (L1→L2 in Moreno et al., 2002; L2→L1 in Ng et al., 2014 and Van der Meij et al., 2011), with the exception of Proverbio et al. (2004) who asked whether the processing of a codeswitch differs by switch direction. Eight professional simultaneous interpreters read sentences that began in either L1 or L2 and whose sentence-final word was either a non-switch, a codeswitch, or a semantically incongruous word. Codeswitches resulted in an increased N400 that was larger when switching into L2 than into L1. Thus, the processing of codeswitches was asymmetric, where switching into L2 incurred greater processing costs than switching into L1. Note that the direction of the asymmetry here is in line with some ERP comprehension studies on isolated-item switching (Alvarez et al., 2003; Chauncey et al., 2008) and behavioral comprehension studies on intra-sentential codeswitching (Bultena et al., 2015a, 2015b; Wang, 2015).

While the Proverbio et al. study is an important step toward understanding how the neurocognitive mechanisms of codeswitching differ by the direction of the switch, there were several methodological choices that constrain the generalizability of the results. First, the participants were simultaneous interpreters, who differ from typical bilinguals in that they knew 1–6 additional languages, and used their first two languages in professional interpretation. Second, analyses of the codeswitches were collapsed across semantically congruous and incongruous words, some of which were also an incongruous part of speech, which may have driven the N400 effect found for codeswitches. Note also that though the authors did not examine the LPC time window, an LPC would not be expected for this study since the conditions were blocked by type such that codeswitches were entirely predictable. The present study will use more typical bilinguals (i.e.

habitual codeswitchers) and current design and analysis practices to examine sentential codeswitches in both language directions to determine if sentential codeswitches incur asymmetric switching costs as found in the single-item language switching studies.

Finally, the switches in the previous neurocognitive studies consist of one word only. These insertions do not reflect the common pattern of codeswitching among Spanish-English bilinguals in the U.S. (Poplack, 1980). In the present study, we will extend previous electrophysiological studies that tested one-word insertional codeswitches (Moreno et al., 2002; Ng et al., 2014; Proverbio et al., 2004; Van der Meij et al., 2011) by examining alternational codeswitching in sentences that start in one language and then continue in the other language. Moreover, we will also examine the effect of codeswitching direction on the processing of these alternational codeswitches.

1.4. The present study

The current study examines the processing of sentence-medial alternational codeswitches in highly proficient Spanish-English bilinguals who were asked to read sentences that switched from the first to the second language, or vice versa. This study adopts a multimodal approach using both behavioral (Experiment 1) and EEG (Experiment 2) techniques, and the EEG recordings are analyzed using both ERP and time-frequency analyses (TFR). TFR analyses, which will be discussed further in the introduction to Experiment 2, provide an additional window into the EEG signal by analyzing the time-frequency representations. They provide complementary, but additional insights into the neural underpinnings of the processing of codeswitches. Thus, our research captures both the end point of processing using behavioral self-paced reading in Experiment 1, and the on-line processing using EEG in Experiment 2 to explore the nature of the neurocognitive processes involved in bilinguals' comprehension of codeswitched sentences.

2. Experiment 1

In this study, Spanish-English bilinguals read codeswitched and non-switched Spanish and English sentences in a self-paced reading task. We expect to find that codeswitches will result in a processing cost (i.e., slower reading times) as compared to non-switched sentences. With respect to the asymmetry of switching costs, if relative proficiency drives the processing of intra-sentential codeswitches, and parallels Bultena et al.'s (2015a, 2015b) findings and single-item studies of language switching (e.g., Alvarez et al., 2003), then we would expect a larger switch cost into the weaker language. But, if self-paced reading invites item-by-item decision making and thus item-based inhibition, like the inhibitory account in Wang's (2015) maze task, then we would expect a larger switch cost into the dominant language, like production studies of single-item language switching (Meuter and Allport, 1999).

2.1. Methods

2.1.1. Participants

22 Spanish-English bilinguals were tested for this study. Data from two participants were discarded due to insufficient accuracy on the comprehension questions during the codeswitching task. 20 participants (16 female) remained (Age: *M*=22.95, *SD*=4.5). All were native speakers of Spanish, with the majority of individuals speaking Central or South American Spanish. Age of acquisition of L2 English varied across participants (*M*=8.10, *SD*=6.0), but participants' self-ratings of their English production and comprehension skills as well as objective measures of proficiency indicate that they were highly proficient speakers of both languages (see Table 1). For these bilinguals, we present proficiency information, and later analyses of switching costs, on the basis of the individuals' relative dominant and weak languages rather than L1 and L2. This was done following results of proficiency measures indicating that L1 was actually the weaker language for some bilinguals who had become more proficient in their L2, which is not uncommon in highly proficient Spanish-English bilinguals in the U.S. (e.g., Heredia and Altarriba, 2001). Dominance was determined by a composite measure of the language proficiency tasks. In addition to self-reported dominance, the following measures were used: self-rated proficiency in production and comprehension, accuracy and reaction time (RT) to real words in the lexical decision task, accuracy and RT in the Boston Naming task (Kaplan et al., 2001), and average RT and comprehension question accuracy in the sentence reading task. For each measure, the dominant language was determined (e.g., higher rated proficiency, faster or more accurate performance). Overall language dominance for a participant was determined to be the language in which they were dominant in for the majority of measures. In this experiment, 11 participants were English-dominant and 9 were Spanish-dominant. All participants reported codeswitching in their daily life. Participants were recruited from the Penn State community via flyers and word-of-mouth and were paid $10/hour for their participation. All participants provided written informed consent before participating.

Table 1
Experiment 1: Individual difference measures for participants' dominant and weaker languages.

Language Proficiency Measures		
	Dominant	*Weaker*
Self-rated production (out of 10)	9.1 (*1.1*)	8.4 (*1.3*)
Self-rated comprehension (out of 10)	9.5 (*1.0*)	9.2 (*.8*)
Sentence Reading Question Accuracy (%)	89.9% (*9.7*)	88.0% (*10.2*)
Sentence Reading Average RT (ms)	346 (*100*)	409 (*116*)
LDT Accuracy (%)	92.0% (*2.7*)	89.7% (*6.5*)
LDT Overall RT (ms)	737 (*107*)	854 (*229*)
BNT Accuracy (%)	66.3% (*8.8*)	47.0% (*18.8*)
BNT RT (ms)	1097 (*169*)	1308 (*256*)
Cognitive Measures		
Flanker Effect (ms)	50 (*25.0*)	
O-Span Recall (out of 60)	40 (8.8)	

Note. Means are reported; standard deviations are in parentheses.

2.1.2. Materials and procedure

The stimuli were comprised of 160 base sentences (see Table 2 for an example sentence in all conditions and the Appendix for all stimuli). Each of these base sentences appeared in four conditions, which manipulated the language in which the sentence started (English or Spanish) and the presence of a codeswitch (yes or no), for a total of 640 sentences. All sentences were semantically and grammatically correct. Sentences were created first in English and then translated into Spanish. The sentences respected the grammar of the specific language, but were as comparable across languages as possible. Spanish versions

Table 2
Experimental conditions.

Language	Codeswitch?	Example sentence
English	Yes	The girl saw some nice shirts in the *tienda frente a su escuela.*
English	No	The girl saw some nice shirts in the *shop across the street from her school.*
Spanish	Yes	La niña vio unas camisas bonitas en el *shop across the street from her school.*
Spanish	No	La niña vio unas camisas bonitas en el *tienda frente a su escuela.*

Note. Codeswitched word: *shop* (Spanish: *tienda*).

of all sentences were checked by two native Spanish speakers (one from Argentina and one from Spain), both habitual codeswitchers, to ensure grammaticality and semantic appropriateness for both peninsular and Latin American speakers of Spanish.

Sentences were created such that at least three words followed the codeswitched word to avoid confounding effects of codeswitching with sentence wrap-up effects. To ensure a full switch to the other language, all words following a codeswitch remained in the codeswitched language. As discussed above, this type of codeswitch has been termed an "alternation" that is often used in communities with two stable languages (for more details, see Muysken (2000)), and is typical of Spanish-English bilingual communities in the U.S. (Poplack, 1980). Moreover, the large majority of codeswitches fell at the determiner-noun boundary, which is a common switch point in codeswitching communities (Herring et al., 2010; Jake et al., 2002; Liceras et al., 2005; Myers-Scotton and Jake, 2014; Pfaff, 1979; Woolford, 1983).

Additionally, the critical words (codeswitch and matched control) adhered to the following criteria: all were nouns (mostly nouns in prepositional phrases or direct objects), did not contain any diacritic markers, and the masculine Spanish determiners were used before all codeswitched English nouns. Previous research has shown that Spanish-English bilinguals tend to default to using the masculine determiner 'el' in determiner-noun codeswitches from Spanish to English, even when the English noun is grammatically feminine in Spanish (e.g., *el fight* where the translation of *fight*, *lucha,* is grammatically feminine; Pfaff, 1979; Valdés Kroff et al., 2016). No critical words were repeated anywhere in the task.

The critical sentences varied between 10 and 22 words (M=14.35, SD=2.32) and the position of the codeswitch within the sentence varied between word 7 and word 16 (M=9.36, SD=1.61). Length of codeswitched words (number of letters) for English was M=6.07, SD=1.93 and for Spanish was M=7.15, SD=1.24. Frequency of codeswitched words for English was M=1.22, SD=.71 and for Spanish was M=1.54, SD=.71. Frequency counts for English codeswitched words were based on the log lemma frequencies from the Celex lexical database (http://celex.mpi.nl; Baayen et al., 1993). Frequencies for Spanish were based on the sum of the singular and plural noun frequencies from the Diccionario de frecuencias de las unidada lingüisticas del Castellano (Alameda and Cuetos, 1995).[1]

An additional 12 sentences were created for practice. Five of these were instructional (e.g., "Here you can practice how you will be reading the sentences"). The remaining seven sentences were identical in design to the experimental sentences, but did not repeat any critical words. The practice sentences were presented in the four conditions of the study.

Four stimulus lists were created from the 640 total sentences (160 base sentences in four conditions). Each list consisted of all 160 base sentences, which were equally distributed into the four conditions with 40 sentences per condition.

Each base sentence appeared in only one condition per list. Lists were pseudo-randomized such that there were no more than three sentences of the same condition in a row, no more than six sentences in a row beginning in either English or Spanish, no more than six sentences in a row containing a codeswitch or non-switch, and no more than nine sentences in a row without a given condition appearing.

To ensure participants actively read the sentences, their task was to answer "yes"/"no" comprehension questions that followed one quarter of the sentences. For example, the comprehension question "*Did the girl see musical instruments across from her school*?" followed the sentence, "*The girl saw some nice shirts in the shop across from her school*". The language of the comprehension questions were the same as the language of non-switch sentences, and was the same as the language of the pre-switch portion of codeswitched sentences. Questions were separated by at least one sentence and at most by seven sentences. The comprehension questions were evenly spread across the four conditions within each list and half of the questions for sentences within a given condition required a "yes" response and half required a "no" response. Practice sentences included comprehension questions in the same manner as experimental trials.

The task consisted of four blocks, each containing 40 sentences and 10 comprehension questions (interspersed throughout the block). Each block lasted about 8 min, depending on participants' reading speed. Short breaks separated blocks during which participants could relax.

2.1.3. Cognitive and language proficiency measures

Participants also completed an Operation Span task (Turner and Engle, 1989) and the Flanker task (Emmorey et al., 2008). Participants completed three language proficiency tasks (in addition to self-ratings of proficiency): a lexical decision task (LDT), the Boston Naming test (BNT, picture naming; Kaplan et al., 2001), and a unilingual self-paced sentence reading task. The three language proficiency tasks were all completed in both English and Spanish, with the order of languages counterbalanced based on participants' self-report of dominance in either English or Spanish.

2.1.4. Procedure

Sentences were presented using a non-cumulative self-paced reading paradigm (Just et al., 1982). Trials began with a fixation cross, followed by a participant-initiated word-by-word presentation of the sentence (see Fig. 1). To advance from the fixation cross and between each word participants pressed a button on a response box. Time spent on each word (reading time; RTs) was used as the dependent measure. Each word was displayed in the center of the screen in black text (Arial font, size 18) on a white background. At the end of the sentence, there was either a fixation cross to signal the start of the next sentence or a question, to which the participant had to make a yes/no decision by pressing one of two buttons. The questions were displayed in full on a single screen and there was no time limit for responding. Participants were instructed to read the sentences as quickly as possible while reading for meaning such that they could successfully answer the comprehension questions.

2.1.5. Data analysis

To ensure that participants were successfully performing the self-paced reading task, accuracy on the comprehension questions was calculated. Participants who scored lower than 75% correct were excluded from analysis (2 participants).

Reading times (RTs) were collected to all words in the sentences. Analyses were performed on RTs to 6 words in the critical region only: the two words before the codeswitched word, the codeswitched word, and the three words following the codeswitched word. The two words before were analyzed to ensure that the reading times did not differ across conditions prior to the switch manipulation. The three words following were analyzed given that effects often spillover into neighboring words in the self-paced reading task (Just et al., 1982). RTs faster than 100 ms and relative outliers (RTs greater than 2.5 standard deviations from the mean) were removed by subject and condition (range of items removed for all 6 critical words by condition: Dominant-Weak codeswitch: 3.1–4.4%; Dominant non-switch: 3.5–4.8%; Weak-Dominant codeswitch: 3.5–4.9%; Weak non-switch: 2.6–4.4%).

For the analyses of all critical words, the language of the target word (Dominant or Weak) was kept constant. As discussed in Section 2.1.1, our analyses focused on the switching effects as a function of individuals' relative dominant and weaker languages, rather than

[1] Length and frequency were measured for codeswitched words in English and Spanish, though were not matched across languages (Spanish words are typically longer than English words, Vitevitch and Rodríguez, 2004; different frequency corpora preclude matching across languages, but r=.78 for English and Dutch frequency of English-Dutch translation pairs drawn from comparable English and Dutch frequency counts in CELEX, see De Groot et al. (1994)).

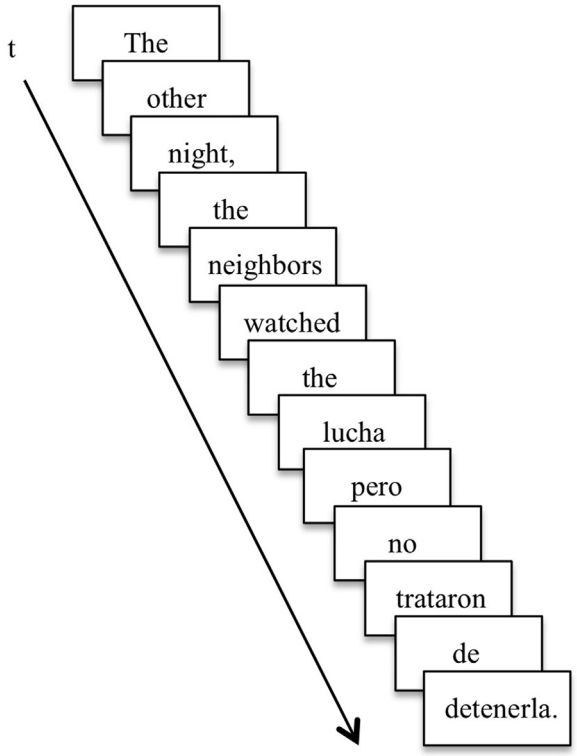

Fig. 1. Example trial in self-paced reading task. Participants pressed a button to advance between words.

Spanish or English. By-subjects (F_1) and by-items (F_2) analyses were conducted for all comparisons.[2] Analyses first examined if there was a general switch cost, across both directions of switching. To do this, first, a series of six 2 Language (Dominant, Weak) by 2 Switch (Switch, non-switch) ANOVAs were conducted on the RTs, one for each of the first four codeswitched words, and one each for the two words prior to the first codeswitched word. Second, we examined switch costs as a function of the direction of the codeswitch with follow-up one-way ANOVAs.[3] For all analyses, to ensure that the critical words from switch and non-switch conditions were always in the same language (in terms of relative dominance), for each of the four codeswitched words, we compared Weak → Dominant codeswitched sentences with Dominant non-switch sentences so that each target word was in participants' dominant language in both switch and non-switch conditions. Likewise, we compared Dominant→Weak codeswitched sentences with Weak non-switch sentences so that each target word was always in participants' weaker language. For each of the two words before the codeswitch, we compared Weak→Dominant codeswitched sentences with Weak non-switch sentences so that each target word was in the weaker language. Likewise, we compared Dominant → Weak codeswitched sentences with Dominant non-switch sentences so each target word was in the Dominant language.

2.2. Results

2.2.1. Comprehension questions

Participants averaged 86.1% (*SD*=4.1; range: 84.5–88.5% across the four critical conditions) accuracy, indicating that they understood the sentences and were sufficiently engaged in the task.

2.2.2. Overall switch versus non-switch sentences

ANOVAs yielded switch effects on the first codeswitched word ($F_1(1, 19)=3.612$, $p=.073$; $F_2(1, 319)=4.547$, $p=.034$), second codeswitched word ($F_1(1, 19)=7.987$, $p=.011$; $F_2(1, 319)=11.708$, $p=.001$), third codeswitched word ($F_1(1, 19)=4.461$, $p=.048$; $F_2(1, 319)=2.249$, $p=.135$), and fourth codeswitched word ($F_1(1, 19)=5.992$, $p=.024$; $F_2(1, 319)=6.774$, $p=.01$), such that codeswitched words were read more slowly than non-switched words (F_1 for first codeswitched word was marginally significant and F_2 for third codeswitched word failed to reach significance). There were also effects of the target language on the first codeswitched word ($F_1(1, 19)=7.543$, $p=.013$, $F_2(1, 319)=36.091$, $p < .001$), second codeswitched word ($F_1(1, 19)=12.112$, $p=.003$, $F_2(1, 319)=11.165$, $p=.001$), third codeswitched word ($F_1(1, 19)=7.584$, $p=.013$, $F_2(1, 319)=20.035$, $p < .001$), and fourth codeswitched word ($F_1(1, 19)=3.352$, $p=.083$; $F_2(1, 319)=16.284$, $p < .001$), such that words in the weaker language were read more slowly than dominant language words. Importantly, for the two words prior to the first codeswitched word, there were no effects of switch (F_1 all $ps > .59$, F_2 all $ps > .43$; see Fig. 2). There were significant effects of language on the second word prior to the switch ($F_1(1, 19)=9.509$, $p=.006$, $F_2(1, 319)=14.355$, $p < .001$) and the word directly preceding the switch ($F_1(1, 19)=3.236$, $p=.088$, $F_2(1, 319)=4.297$, $p=.039$), indicating that words in the weaker language were read more slowly than words in the dominant language.

Although there were no significant interactions between switch and language on the first codeswitched word and the three words after the first codeswitch (F_1 all $ps > .07$, F_2 all $ps > .24$) or the two words before the switch (F_1 all $ps > .32$, F_2 all $ps > .26$), based on our *a priori* hypotheses we examined each codeswitching direction separately.

2.2.3. Switching from weaker into dominant language[4]

When switching from the weaker language into the dominant language, codeswitched words were read more slowly than non-switched (dominant) words at the first codeswitched word (switch cost: 39 ms; $F_1(1, 19)=12.193$, $p=.002$, $F_2(1, 319)=8.808$, $p=.003$), second codeswitched word (switch cost: 50 ms; $F_1(1, 19)=13.929$, $p=.001$, $F_2(1, 319)=5.233$, $p=.023$), and the fourth codeswitched word (switch cost: 19 ms; $F_1(1, 19) =6.586$, $p=.019$, $F_2(1, 319)=19.277$, $p < .001$); analyses on the third codeswitched word did not reach significance (switch cost: 17 ms; see Fig. 2). There were no effects of switch (weak→dominant switch versus weak non-switch) on the two words prior to the first codeswitched word (F_1 all $ps > .65$, F_2 all $ps > .47$).

2.2.4. Switching from dominant into weaker language

When switching from the dominant into the weaker language, there was a marginal effect of switch such that switches into the weaker language were read more slowly than non-switched words at the second codeswitched word (switch cost: 41 ms; $F_1(1, 19)=4.063$, $p=.058$, $F_2(1, 319)=3.747$, $p=.054$) and third codeswitched word (switch cost: 15 ms; $F_1(1, 19)=6.338$, $p=.021$, $F_2(1, 319)=.61$, $p=.435$); the remaining differences did not reach statistical significance (first codeswitched word switch cost: 7 ms; fourth codeswitched word switch cost: 17 ms; see Fig. 3). There were no effects of the factor switch (dominant→weak switch versus dominant non-switch) on the two words prior to the codeswitched word (F_1 all $ps > .34$, F_2 all $ps > .23$).

[2] Note that for the F_2 analyses, the degrees of freedom (DF) reflect that there are 160 base sentences, each with the critical noun in two languages, resulting in 320 total items. Thus the degrees of freedom are (1, 319).

[3] Note that we are presenting our results without alpha correction. Alpha-adjustments would apply to the two follow-up ANOVAs and using the conservative Bonferroni correction, the alpha-adjustment would be set at .025 rather than .05. At alpha=.025, our pattern of results remains the same.

[4] The same analyses were run with Language (L1 Spanish, L2 English) as a factor rather than Language (Dominant, Weak) and the same pattern of results were found: there was an effect of switch on the first three codeswitched words for switches from L1 to L2, and on the first and third codeswitched words for switches from L2 to L1. For both codeswitching directions, there were no effects of switch on the two words before the codeswitch.

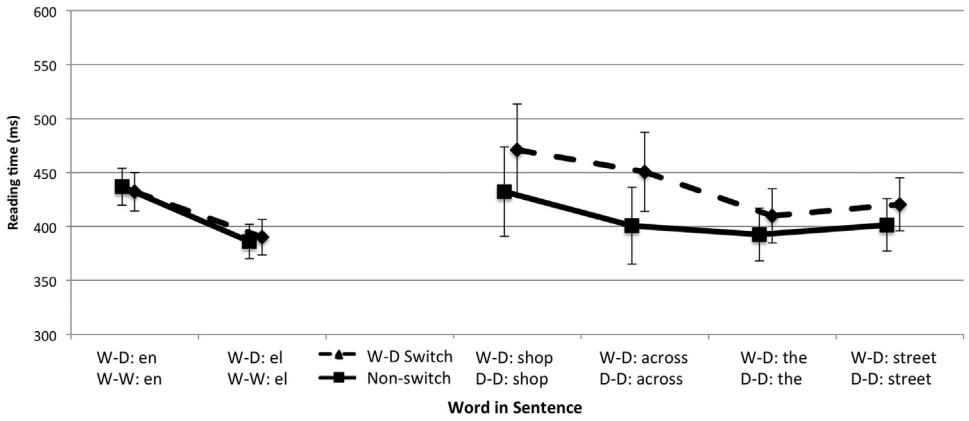

Fig. 2. Reading times of Weak→Dominant switches (dotted) and non-switches (solid) for the two words prior to the codeswitch (left portion of graph) and the codeswitched word and the three words following (right portion of graph). The X-axis labels gives words in a sentence (see Table 2) for each condition (D=dominant language; W=weaker language), for the case of a bilingual who is dominant in English (the sentences would be reversed for a bilingual who is dominant in Spanish). Error bars represent standard error.

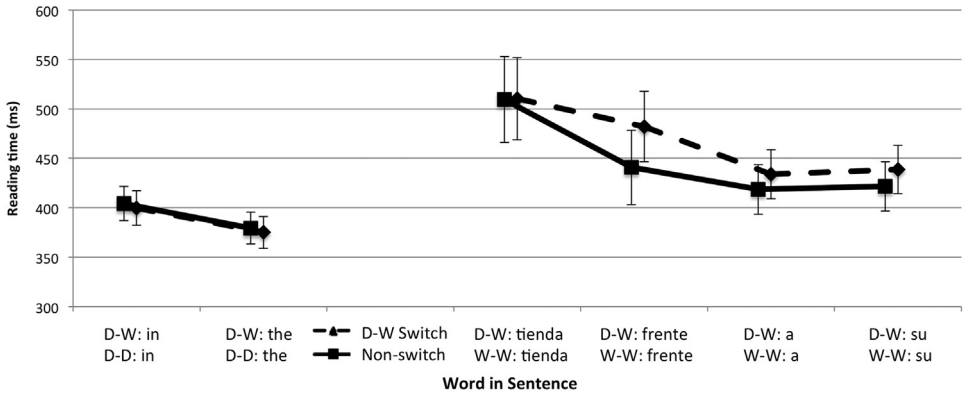

Fig. 3. Reading times of Dominant→Weak switches (dotted) and non-switches (solid) for the two words prior to the codeswitch (left portion of graph) and the codeswitched word and the three words following (right portion of graph). The X-axis labels gives words in a sentence (see Table 2) for each condition (D=dominant language; W=weaker language), for the case of a bilingual who is dominant in English (the sentences would be reversed for a bilingual who is dominant in Spanish). Error bars represent standard error.

2.3. Discussion

Experiment 1 used the word-by-word self-paced reading task to investigate how Spanish-English bilinguals read sentences that contained intra-sentential codeswitches in both switching directions. Results showed an overall effect of switching such that the first four codeswitched words were read more slowly than non-switched words. Although there were no statistically significant interactions between language and switching direction on any of the codeswitched word positions, subsequent analyses focusing on each switching direction separately indicated that there were somewhat larger switching costs when switching into the dominant language than into the weaker language.

The observed pattern of switching costs in reading times associated with intra-sentential codeswitching does not converge with recent behavioral studies which examined intra-sentential alternational codeswitches (Bultena et al., 2015a, 2015b; Wang, 2015), and observed that switching into the weaker language (L2) was more costly than switching into the dominant language (L1). However, these studies all used bilinguals who had lower L2 proficiency levels than the highly fluent Spanish-English bilinguals we tested, and were also not habitual codeswitchers as were the bilinguals tested in this study.

The present findings of more costly processing into the dominant rather than the weaker language pattern more with production, rather than comprehension, studies of single-item language switching. This asymmetrical pattern has traditionally been associated with item-based top-down inhibitory processing (e.g., Green, 1998), suggesting that readers were engaged in item-by-item decision-making (but see Declerck and Philipp (2015) for a discussion of the relationship between asymmetrical switching costs and inhibitory processing as well as persisting activation). While reading comprehension may generally engage bottom-up exogenous control (Grainger et al., 2010), the self-paced reading task, in which a decision is required on each word, may elicit top-down endogenous control processes, resulting in the observed asymmetry.

These reading times demonstrate a measureable switching cost related to the comprehension of intra-sentential codeswitching. But, reading times reflect the end-stage of processing and do not reveal the neurocognitive processing that unfolds over time during reading. To further explore the nature of the neurocognitive processes underlying the comprehension of codeswitched sentences, we will capitalize on the fine-grained temporal resolution of EEG to examine the temporal dynamics of component processes associated with codeswitching that drive and ultimately determine a behavioral response, but occur before it is realized. EEG also provides insight into the nature of the cognitive cost involved in the comprehension of intra-sentential codeswitching as it unfolds in real time. More specifically, if intra-sentential codeswitches incur a cost at the level of lexical access and semantic integration, then the language-switched items should elicit an increased N400 ERP response relative to the non-switched words. If intra-sentential codeswitches incur a cost at the sentence-restructuring level, the language-switched words should elicit an increased LPC ERP response.

3. Experiment 2

In this experiment, we used EEG to examine the cognitive and neural mechanisms underlying the comprehension of intra-sentential

Table 3
Experiment 2: Individual difference measures for participants' dominant and weaker languages.

Language Proficiency Measures		
	Dominant	*Weaker*
Self-rated production (out of 10)	9.1 (*.9*)	7.9 (*1.4*)
Self-rated comprehension (out of 10)	9.6 (*.6*)	8.7 (*1.0*)
Sentence Reading Question Accuracy (%)	88.7% (*8.1*)	83.8% (*10.5*)
Sentence Reading Average RT (ms)	320 (*87*)	401 (*128*)
LDT Accuracy (%)	91.6% (*5.7*)	86.6% (*6.5*)
LDT Overall RT (ms)	656 (*112*)	851 (*283*)
BNT Accuracy (%)	67.0% (*10.4*)	50.9% (*15.6*)
BNT RT (ms)	1109 (*262*)	1290 (*278*)
Cognitive Measures		
Flanker Effect (ms)	55 (*23.3*)	
O-Span Recall (out of 60)	34 (*12.9*)	

Note. Means are reported; standard deviations are in parentheses.

codeswitching. Previous ERP studies of intra-sentential codeswitching suggest that switches incur extra processing efforts as compared to non-switches. Three studies (Moreno et al., 2002; Ng et al., 2014; Van der Meij et al., 2011) have found that codeswitched words elicit a biphasic response consisting of a LAN or N400 followed by a late positivity. These studies each examined codeswitching in only one direction, removing the ability to determine if direction modulates the switch cost. Proverbio et al. (2004) included both directions of switching and found only an N400 response that was larger into the L2, but their sentences were blocked by type and the LPC time window was not analyzed.

In Experiment 2, we used the EEG/ERP methodology to examine intra-sentential codeswitching in two switching directions. We also added analyses of neural oscillations. In addition to computing ERPs, EEG data can be analyzed in the time-frequency domain to examine the oscillatory dynamics of the signal, in which time-frequency representations (TFRs) reflect ongoing synchrony or de-synchrony in functional neural networks (Bastiaansen and Hagoort, 2006). An event-related synchronization, or power increase, occurs when a functional network comes online and the neurons fire more synchronously in the face of a stimulus, while an event-related de-synchronization, or power decrease, reflects a functional network that becomes disengaged and disrupted by the stimulus. These oscillations are measured as power, or activity, in different frequency bands (delta: .5–2 Hz; theta: 4–7 Hz; alpha: 8–12 Hz; lower beta: 15–18; upper beta: 20–30 Hz; gamma: 30–60 Hz). While both TFRs and ERPs reflect the time-locked EEG activity, TFRs additionally reflect the non-phase-locked EEG activity that is lost in the ERP signal. Thus, TFR provides an alternate and potentially more comprehensive measure of neurocognitive processing.

Language research has only begun to incorporate TFR analyses, and to date no study has applied this technique to the study of intra-sentential codeswitching. The emerging body of TFR studies of language processing suggests that lexico-semantic processing elicits power increases in theta and gamma bands (e.g., Bakker et al., 2015; Bastiaansen and Hagoort, 2006, 2015). Theta increases have also been found to index inhibition in isolated-item language switching related to the word-level suppression of the L1 (Liu et al., 2017). Sentence-level processing, including syntactic unification, relates to power decreases in lower beta (Bastiaansen and Hagoort, 2015). Lower beta has been more generally associated with the maintenance of or change to the current processing set, which when applied to language processing, relates to the construction of a sentence-level meaning representation and whether or not incoming information (e.g., words in a sentence) cues the language system to change the current processing in a manner that will accommodate the new information (Engel and Fries, 2010; Lewis et al., 2015; Weiss and Mueller, 2012).

The current study will use both ERPs and TFRs to examine whether the neurocognitive processing of intra-sentential codeswitching differs across switching directions. Since EEG reveals more fine-grained information on lexical-level and sentence-level restructuring processes, which may be impacted by relative language proficiency, we may find evidence of an asymmetry where more effortful processing is required for switches into the weaker language. Thus, for switches into the weaker language, we would expect N400 ERP and theta band time-frequency effects if the processing of codeswitches is driven by lexico-semantic integration, and we would expect LPC ERP and lower beta band time-frequency effects if the processing relies on sentence-level restructuring. Alternatively, if neural activity parallels the behavioral responses (Experiment 1), we should see symmetrical or somewhat stronger switching effects into the dominant language reflecting item-based inhibitory processing, evidenced by a theta TFR effect.

3.1. Methods

3.1.1. Participants

28 Spanish-English bilinguals were tested. Data from two participants were discarded due to excessive blink artifact in the EEG signal and data from another participant was discarded due to insufficient accuracy on the comprehension questions during the codeswitching task. Data from the remaining 25 participants (20 female) were analyzed (age: *M*=23.08, *SD*=4.8). All were native speakers of Spanish, with the majority speaking Central or South American Spanish. Age of acquisition of L2 English varied across participants (*M*=6.88, *SD*=4.4), but self-ratings of English production and comprehension skills as well as objective measures of proficiency indicate that they were highly proficient speakers of English (see Table 3). All but 4 participants reported codeswitching frequently in their daily life. All were right-handed and reported normal or corrected-to-normal vision, and no brain trauma. Participants were recruited from the Penn State community via flyers and word-of-mouth and were paid $10/hour for their participation. All participants provided informed consent before the experiment.

3.1.2. Materials

Materials for Experiment 2 were identical to Experiment 1. The three critical words were the first codeswitched word and the word following (second codeswitched word, to examine the duration of switching effects), as well as the word before the codeswitch to ensure that no effects of switching are found before the switch manipulation.

3.1.3. Procedure and EEG recording

Participants completed the codeswitching task while EEG was recorded. Sentences were presented using rapid serial visual presentation (RSVP) with words presented at a fixed presentation rate: 300 ms for words with a 200 ms blank interstimulus interval (ISI). Participants completed the Language History Questionnaire during setup of the EEG cap, and completed the cognitive and language proficiency tasks after the codeswitching task. All other procedure details, including order of the tasks, remained the same.

Participants were seated in a comfortable chair about 3 feet from the computer in a sound-attenuated darkened chamber. An elastic cap (Brain Products ActiCap, Germany) with 31 active Ag/AgCl electrodes was placed on the participant's head. Electrode locations consisted of five sites along the midline (Fz, FCz, Cz, Pz, Oz) and 26 lateral electrodes (FP1/2, F7/8, F3/4, FC5/6, FC1/2, T7/8, C3/4, CP5/6, CP1/2, P7/8, P3/4, O1/2, PO9/10). In order to monitor vertical eye movements/blinks, bipolar recordings were made above and below the left eye, and the outer canthus of each eye. Electrodes were referenced to a vertex reference (electrode FCz) and re-referenced offline to an average of the left and right mastoids. The electroencephalogram (EEG) was amplified by a NeuroScan SynampsRT amplifier using a .05–100 Hz bandpass filter and continuously sampled at a rate of

500 Hz. Electrode impedances were kept below 10 kΩ.

3.1.4. ERP preprocessing and analysis

Preprocessing and measurement of the ERP data was done in ERPlab (Lopez-Calderon and Luck, 2014). An off-line 30 Hz low-pass filter was applied. For each participant, separate ERPs were averaged off-line at each electrode site for each experimental condition, relative to a 200 ms prestimulus baseline. Trials contaminated with eye artifact (dominant to weak codeswitch: 10.7%; dominant non-switch: 11.2%; weak to dominant codeswitch: 11.7%; weak non-switch: 11.4%) were not included.

EEG was time-locked to the onset of the critical word for the first codeswitched word and word before. For the second codeswitched word, in order to avoid baseline issues resulting from switching effects on the first codeswitched word, EEG was time-locked to the onset of the first codeswitched word with an epoch lasting through the word following (Luck, 2014). Analyses of the critical words were conducted on mean amplitudes with a baseline of 200 ms pre-stimulus activity. In accordance with previous studies and visual inspection of the data, two time windows were analyzed, corresponding to the epochs of the N400 and LPC: 300–500 ms and 500–900 ms post word onset (for the second codeswitched word, this corresponds to 800–1000 ms and 1000–1400 ms post first codeswitched word onset).

For all comparisons of interest, two repeated measures analyses of variance (ANOVA) were performed to examine the scalp distribution of the ERP effect. One ANOVA focused on midline electrodes and included a factor of electrode group (Fz, Cz, Pz). The second ANOVA included a factor of anteriority (anterior, posterior) and laterality (right, left hemisphere). For these factors, electrodes were grouped into regions of interest: right frontal ("RF": F4, F8, FC2, FC6); left frontal ("LF": F3, F7, FC1, FC5); right posterior ("RP": CP2, CP6, P4, P8); left posterior ("LP": CP1, CP5, P3, P7). A Greenhouse-Geisser correction was applied to analyses with more than one degree of freedom in the numerator. Significant interactions were examined further with simple effects tests and planned comparisons.

For analyses of all three critical words, the language of the target word was kept constant. Analyses first examined if there was a general switch cost, across both directions of switching. To do this, mean amplitudes, separately for the two time windows, were compared for the codeswitched words (and matched controls) in sentences containing codeswitches (Dominant→Weak and Weak→Dominant) and non-switched sentences (Dominant and Weak unilingual sentences). Second, we examined switch costs as a function of the direction of the codeswitch. As in Experiment 1, all analyses were based on participants' dominant and weak languages. Dominance was again determined by a composite measure of the language proficiency tasks. In this experiment, 14 participants were English dominant and 11 were Spanish dominant.

3.1.5. Oscillatory preprocessing and analysis

Time-frequency preprocessing and analysis was done in the Fieldtrip toolbox (Oostenveld et al., 2010) on the first codeswitched word. The EEG was re-referenced offline to the averaged left and right mastoids, and a notch filter at 60, 120, and 180 Hz was applied to remove line noise. Epochs of 400 ms pre-stimulus to 1200 ms post-stimulus were extracted. Trials contaminated with eye artifact were removed by manual inspection (7.4% of all critical trials).

Time-frequency representations (TFRs) were computed for frequencies between 4 and 50 Hz by applying a Hanning taper with a 400 ms window, followed by a Fourier transform in steps of 50 ms and 1 Hz. TFRs were computed for individual trials and subsequently averaged across trials for each participant and condition separately. Power changes were quantified as the ratio of the increase or decrease of the epoch relative to a 200 ms baseline.

Following common practice in TFR analysis (e.g., Bastiaansen et al., 2015), we performed cluster-based permutation statistics (for more details, see Maris and Oostenveld (2015)) using the Fieldtrip toolbox. The cluster-based permutation statistics can only compare two conditions at a time. Thus, to compare all four experimental conditions in an analysis akin to a 2×2 ANOVA, we first created two difference conditions (dominant-weak codeswitch minus weak language non-switch; weak-dominant codeswitch minus dominant language non-switch), and compared those difference conditions using the cluster-based permutation statistics.

Separate analyses were performed for the following frequency ranges, corresponding to frequency bands of interest: 4–7 Hz Theta; 8–12 Hz Alpha; 15–18 Hz Lower Beta; 20–30 Hz Upper Beta; 30–40 Hz Lower Gamma; 40–50 Hz Upper Gamma. Following ERP analysis, the language of the target word was kept constant. Dominance was also the same as for ERP.

3.2. Results

3.2.1. Comprehension questions

Participants averaged 87.0% accuracy (*SD*=4.4; range: 85.6–87.9% across the four critical conditions), indicating that they understood the sentences and were sufficiently engaged in the task.

3.2.2. Event-related potential results

3.2.2.1. First codeswitched word

3.2.2.1.1. ERP: overall switch versus non-switch sentences. There were no significant effects in the 300–500 ms time window (all *p*s > .19), but in the 500–900 ms LPC time window there was a main effect of switch such that switched words were more positive than non-switched words (lateral: $F(1, 24)=4.145$, $p=.05$). While there were no significant interactions between switch and language (all *p*s > .34), based on our *a priori* hypotheses about differences related to direction of codeswitch, we examined each switching direction separately.

3.2.2.1.2. ERP: switching into the dominant language[5]. Grand mean waveforms for switch (weak to dominant) and non-switch (dominant non-switch) conditions where the target language is dominant are plotted in Fig. 4. Visually, there are no differences between the conditions, which was confirmed by statistical analyses. In the 300–500 ms time window, there were no significant differences between the conditions (all *p*s > .43). In the 500–900 ms time window, there was an interaction between switch and anteriority ($F(1, 24)=5.237$, $p=.031$), but follow-up analyses revealed no significant differences between switch and non-switch conditions at anterior or posterior sites (all *p*s > .07). So, for switches into the dominant language, there were no significant differences between switched and non-switched sentences.

3.2.2.1.3. ERP: switching into the weaker language. Grand mean waveforms for switch (dominant to weak) and non-switch (weak non-switch) conditions where the target language is weak are plotted in Fig. 5. Visual inspection reveals a late, posterior positivity. In the 300–500 ms time window, there were no significant differences between the conditions (all *p*s > .11). However, in the 500–900 ms time window, there were main effects of switch (midline: $F(1, 24)=5.583$, $p=.027$; lateral: $F(1, 24)=6.221$, $p=.02$) wherein the switch condition was more positive than the non-switch condition. There was also a marginal interaction of switch and scalp topography (lateral switch by anteriority: $F(1, 24)=4.047$, $p=.056$). Follow-up ANOVAs showed

[5] The same analyses were run with Language (L1 Spanish, L2 English) as a factor rather than Language (Dominant, Weak) and a similar pattern of results was found: a small N400 effect for switches into English (for most participants the dominant language) on the first codeswitched word, which was not sustained for the second codeswitched word, and an LPC effect for switches into Spanish (for most participants the weaker language) for both the first and second codeswitched word.

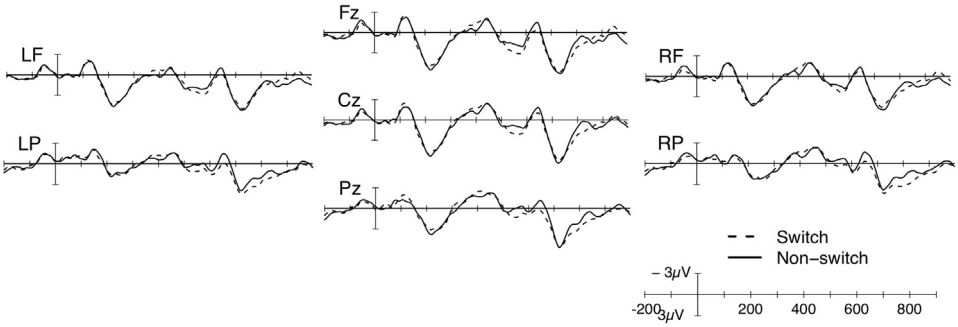

Fig. 4. Grand mean waveforms for the codeswitched word for Weak→Dominant switch (dotted) and dominant-language non-switch (solid) conditions. Onset of the codeswitched word is indicated by vertical bar. The calibration plot shows amplitude is plotted on the y-axis (negative plotted up). Time is plotted on the x-axis; each tick mark indicates 100 ms. LF=left frontal; RF=right frontal; LP=left posterior; RP=right posterior.

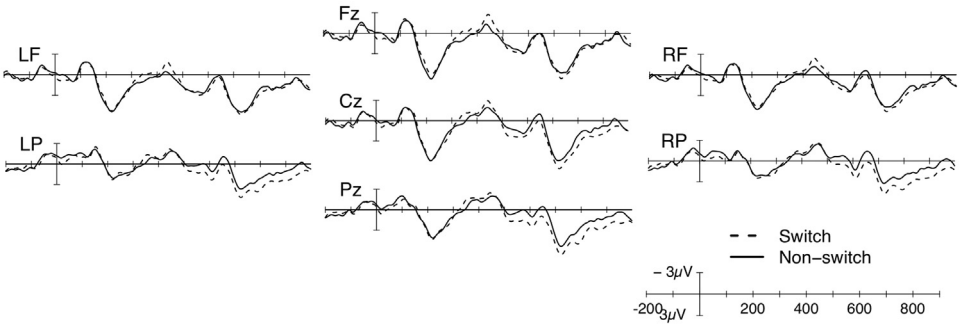

Fig. 5. Grand mean waveforms for the codeswitched word for Dominant→Weak switch (dotted) and weak-language non-switch (solid) conditions. Onset of the codeswitched word is indicated by vertical bar. The calibration plot shows amplitude is plotted on the y-axis (negative plotted up). Time is plotted on the x-axis; each tick mark indicates 100 ms. LF=left frontal; RF=right frontal; LP=left posterior; RP=right posterior.

that switches were more positive than non-switches at lateral posterior sites (F(1, 24)=4.257, p=.05). So, for switches into the weaker language, there is a larger late, posterior positivity to codeswitches than to non-switches.

3.2.2.2. Second codeswitched word

3.2.2.2.1. ERP: overall switch versus non-switch sentences. In the 300–500 ms window (800–1000 ms post onset first codeswitched word), there were significant effects of target language, such that sentences ending in the dominant language were more negative than those ending in the weaker language (midline: F(1, 24)=5.533, p=.027; lateral: F(1, 24)=6.955, p=.014), but no effects of switch or interactions of switch and target language (all ps > .13). In the LPC time window, there were no effects of target language, switch, or interactions of switch and target language (all ps > .15). However, given our *a priori* hypotheses, and to follow up on differential effects found on the first codeswitched word (see just above), we examined each switching direction separately.

3.2.2.2.2. ERP: switching into the dominant language. Grand mean waveforms for switch (weak to dominant) and non-switch (dominant non-switch) conditions where the target language is dominant are plotted in Fig. 6. Visual inspection of the waveforms suggest there are no substantial differences between the waveforms for switch and non-switch conditions, but the statistical analyses yielded an interaction of switch and scalp topography in the 300s–500 ms (800–1000 ms post codeswitched onset) time window (lateral switch by anteriority: F(1, 24)=5.404, p=.029). Follow-up ANOVAs revealed that switch words were more negative than non-switch words at anterior sites (F(1, 24)=5.126, p=.033). In the LPC time window, there was an interaction of switch and scalp topography (lateral switch by anteriority: F(1, 24)=4.721, p=.04), but follow-up ANOVAs revealed no differences between switch and non-switch conditions at anterior or posterior sites (all ps > .24).

3.2.2.2.3. ERP: switching into the weaker language. Grand mean waveforms for switch (dominant to weak) and non-switch (weak non-switch) conditions where the target language is weak are plotted in Fig. 7. Visual inspection reveals a posterior positivity continuing from the first codeswitched word. In the 300–500 ms time window (800–1000 ms post onset of the first codeswitched word), there were interactions of switch with scalp topography (midline switch by electrode: F(2, 48)=4.659, p=.036; lateral switch by anteriority: F(1, 24)=7.210, p=.014). Follow-up ANOVAs revealed that switches were more positive than non-switches at lateral posterior sites (F(1, 24) =6.424, p=.018). In the LPC time window, there was an interaction of switch and scalp topography (lateral switch by anteriority: F(1, 24) =5.873, p=.023), but follow-up analyses revealed no significant effects (all ps > .13). So, for switches into the weaker language, there was a posterior positivity for the second codeswitched word.

3.2.2.3. Word before first codeswitched word

3.2.2.3.1. ERP: overall switch versus non-switch sentences. There were no significant differences between switch and non-switch sentences in either the 300–500 ms time window (all ps > .064) or the 500–900 ms time window (all ps > .07).

3.2.2.3.2. ERP: switching into the dominant language. Grand mean waveforms for switch (weak to dominant) and non-switch (weak non-switch) conditions where the start language is weak and target codeswitch language is dominant are plotted in Fig. 8. Visually, there are no differences between the conditions, which was confirmed in the statistical analyses. There were no significant differences between the conditions in the 300–500 ms time window (all ps > .24)

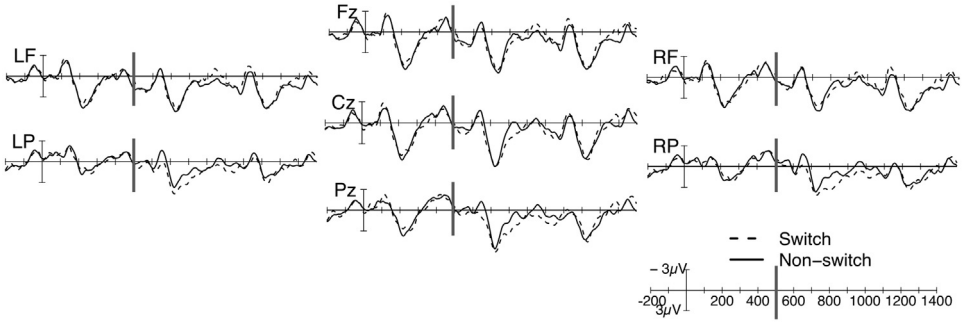

Fig. 6. Grand mean waveforms for the second codeswitched word for Weak→Dominant switch (dotted) and dominant-language non-switch (solid) conditions. Onset of the codeswitched word is indicated by vertical bar; onset of the second codeswitched word is indicated by the vertical bar at 500 ms. The calibration plot shows amplitude is plotted on the y-axis (negative plotted up). Time is plotted on the x-axis; each tick mark indicates 100 ms. LF=left frontal; RF=right frontal; LP=left posterior; RP=right posterior.

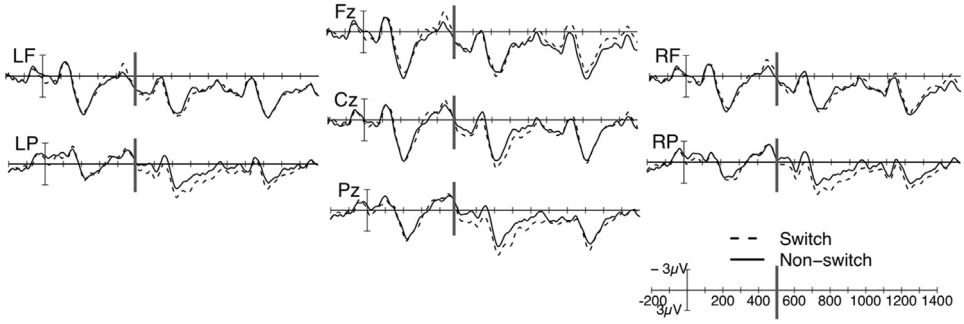

Fig. 7. Grand mean waveforms for the second codeswitched word for Dominant→Weak switch (dotted) and weak-language non-switch (solid) conditions. Onset of the codeswitched word is indicated by vertical bar; onset of the second codeswitched word is indicated by the vertical bar at 500 ms. Onset of codeswitched word is indicated by vertical bar. The calibration plot shows amplitude is plotted on the y-axis (negative plotted up). Time is plotted on the x-axis; each tick mark indicates 100 ms. The vertical bar at 500 ms indicates the onset of the second codeswitched word. LF=left frontal; RF=right frontal; LP=left posterior; RP=right posterior.

or 500–900 ms time window (all *p*s > .38). Thus, for switches into the dominant language, there are no differences between switch and non-switch sentences on the word before the codeswitch.

3.2.2.3.3. ERP: switching into the weaker language. Grand mean waveforms for switch (dominant to weak) and non-switch (dominant non-switch) conditions where the target language is weak are plotted in Fig. 9. Visually, there are no differences between the conditions, which was confirmed by the statistical analyses. There were no significant differences between the conditions in the 300–500 ms time window (all *p*s > .14) or 500–900 ms time window (all *p*s > .52). Thus, also for switches into the weaker language, there are no differences between switch and non-switch sentences on the word before the codeswitch.

3.2.2.4. ERP: correlation analyses. The asymmetrical switching costs in the ERP data, where there was an LPC effect for codeswitched sentences only when switching into the weaker language, suggest that the mechanism underlying the switching cost in the comprehension of codeswitched sentences may be relative language proficiency: switching into a weaker language requires more effortful processing and sentence-level restructuring. To explore this possibility, we correlated the magnitude of the switch cost for switches from the dominant to the weaker language with participants' relative language dominance on three language proficiency measures: the Boston Naming test (BNT), the lexical decision task (LDT), and the unilingual self-paced sentence reading task. To obtain these measures, performance on the proficiency tasks (BNT, overall LDT, comprehension questions for sentence reading) in the weaker language was subtracted from performance on

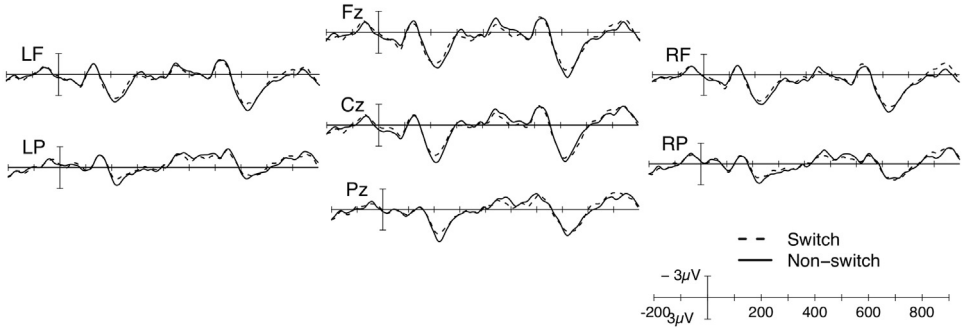

Fig. 8. Grand mean waveforms for the word prior to the codeswitched word for weak→dominant switch (dotted) and weak non-switch (solid) conditions. Onset of the word prior to the codeswitched word is indicated by vertical bar. The calibration plot shows amplitude is plotted on the y-axis (negative plotted up). Time is plotted on the x-axis; each tick mark indicates 100 ms. LF=left frontal; RF=right frontal; LP=left posterior; RP=right posterior.

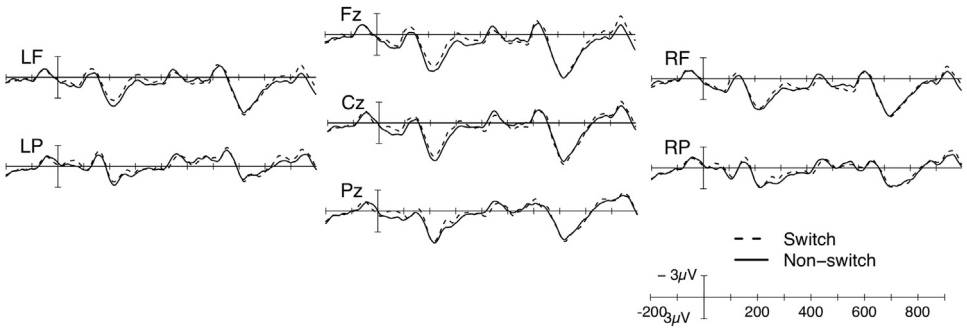

Fig. 9. Grand mean waveforms for the word prior to the codeswitched word for dominant→weak switch (dotted) and dominant non-switch (solid) conditions. Onset of the word prior to the codeswitched word is indicated by vertical bar. The calibration plot shows amplitude is plotted on the y-axis (negative plotted up). Time is plotted on the x-axis; each tick mark indicates 100 ms. LF=left frontal; RF=right frontal; LP=left posterior; RP=right posterior.

these tasks in the dominant language for accuracy measures, and performance on the proficiency tasks in the dominant language was subtracted from performance on these tasks in the weaker language for reaction time measures, in order to have positive values reflect higher proficiency in the dominant language for both accuracy and reaction time. The magnitude of the LPC effect at Pz (the critical electrode site for the LPC) was positively correlated with relative dominance on BNT accuracy (first codeswitched word: r=.561, p=.008; second codeswitched word: r=.430, p=.05), and it was positively correlated with relative dominance on LDT reaction time (first codeswitched word: r=.546, p=.005; second codeswitched word: r =.568, p=.003), such that a larger LPC was associated with a larger discrepancy in proficiency across the languages in both tasks. Similarly, lateral posterior sites also correlated with BNT accuracy relative dominance (LP: first codeswitched word: r=.458, p=.037; second codeswitched word: r=.229, p=.318; RP: first codeswitched word: r=.524, p=.015; second codeswitched word: r=.390, p=.08) and LDT reaction time relative dominance (LP: first codeswitched word: r=.475, p=.016; second codeswitched word: r=.426, p=.034; RP: first codeswitched word: r=.522, p=.007; second codeswitched word: r=.526, p=.007). These results further support the notion that the comprehension of codeswitched sentences is driven by relative language proficiency.

3.2.2.5. Event-related potential results summary. The ERP results showed an LPC effect for switches from the dominant to the weak language that persisted into the second codeswitched word, while there was no ERP effect for switches from the weak to the dominant language on the first or second codeswitched word. As expected, there were no effects on the word before the codeswitched word in either switching direction. Correlation analyses further showed that the magnitude of the LPC effect for dominant to weak switches was larger as the proficiency difference between L1 and L2 increased.

3.2.3. Time-frequency results

3.2.3.1. First codeswitched word

3.2.3.1.1. TFR: overall switch versus non-switch sentences. For the comparison of the difference conditions (dominant-weak codeswitch minus weaker language non-switch, 'DW-WW'; weak-dominant codeswitch minus dominant language non-switch, 'WD-DD'), there were significant clusters in the alpha and lower beta band and no significant clusters in theta, upper beta, or lower or upper gamma. For alpha, there was a power decrease (p=.002) between 350 and 950 ms for the DW-WW condition relative to the WD-DD condition. This effect was widespread over central, followed by centroparietal sites with a right lateralization towards the end of the window (see Fig. 10, part A). For lower beta, there was a power decrease (p=.002) between 250 and 950 ms for the DW-WW condition relative to the WD-DD condition over posterior midline moving to central sites (see Fig. 10, part B).

3.2.3.1.2. TFR: switching into the dominant language. The comparison between weak to dominant codeswitches and dominant language non-switches (see Fig. 11) revealed one significant cluster in the theta band, but no significant clusters in alpha, lower or upper beta, or lower or upper gamma. For theta, there was a power increase (p=.018) from 300 to 650 ms over right frontal, then central sites (see Fig. 12).

3.2.3.1.3. TFR: switching into the weaker language[6]. The comparison between dominant to weak codeswitches and weak language non-switches (see Fig. 13) revealed one significant cluster in lower beta, with no significant clusters in theta, alpha, upper beta, or lower or upper gamma. For lower beta, there was a power decrease (p=.009) for switched as compared to non-switched words from 300 to 600 ms over posterior to frontal sites (see Fig. 14).

3.2.3.2. Time-frequency results summary. Time-frequency analysis revealed a power increase for switches into the dominant language in the theta band (4–7 Hz) from 300 to 650 ms right frontal, then central sites, and a power decrease for switches into the weaker language in the lower beta band (15–18 Hz) from 300 to 600 ms over posterior to frontal sites.

3.3. Discussion

In Experiment 2, Spanish-English bilinguals read codeswitched and non-switched sentences while EEG was recorded. Both ERP and TFR analyses were conducted. ERP analyses of the first and second codeswitched word in each switching condition showed that there was no switch effect on the first codeswitched word and a small anterior negativity on the second codeswitched word when switching from the weaker into the dominant language, but there was a larger LPC incurred by switched as compared to non-switched sentences when switching from the dominant into the weaker language on the first codeswitched word that extended into the early time window (300–500 ms) of the word following the codeswitch. Importantly, we found no effects on the word presented prior to the first codeswitched word and its non-switched control.

[6] The same analyses were run with conditions based on L1 Spanish/L2 English (English-Spanish codeswitch, Spanish non-switch, Spanish-English codeswitch, English non-switch) and the same pattern of results were found: for switches from English into Spanish, there was a power decrease in lower beta band (300–600ms, p=.013); for switches from Spanish into English, there was a power increase in theta band (300–650ms, p=.018).

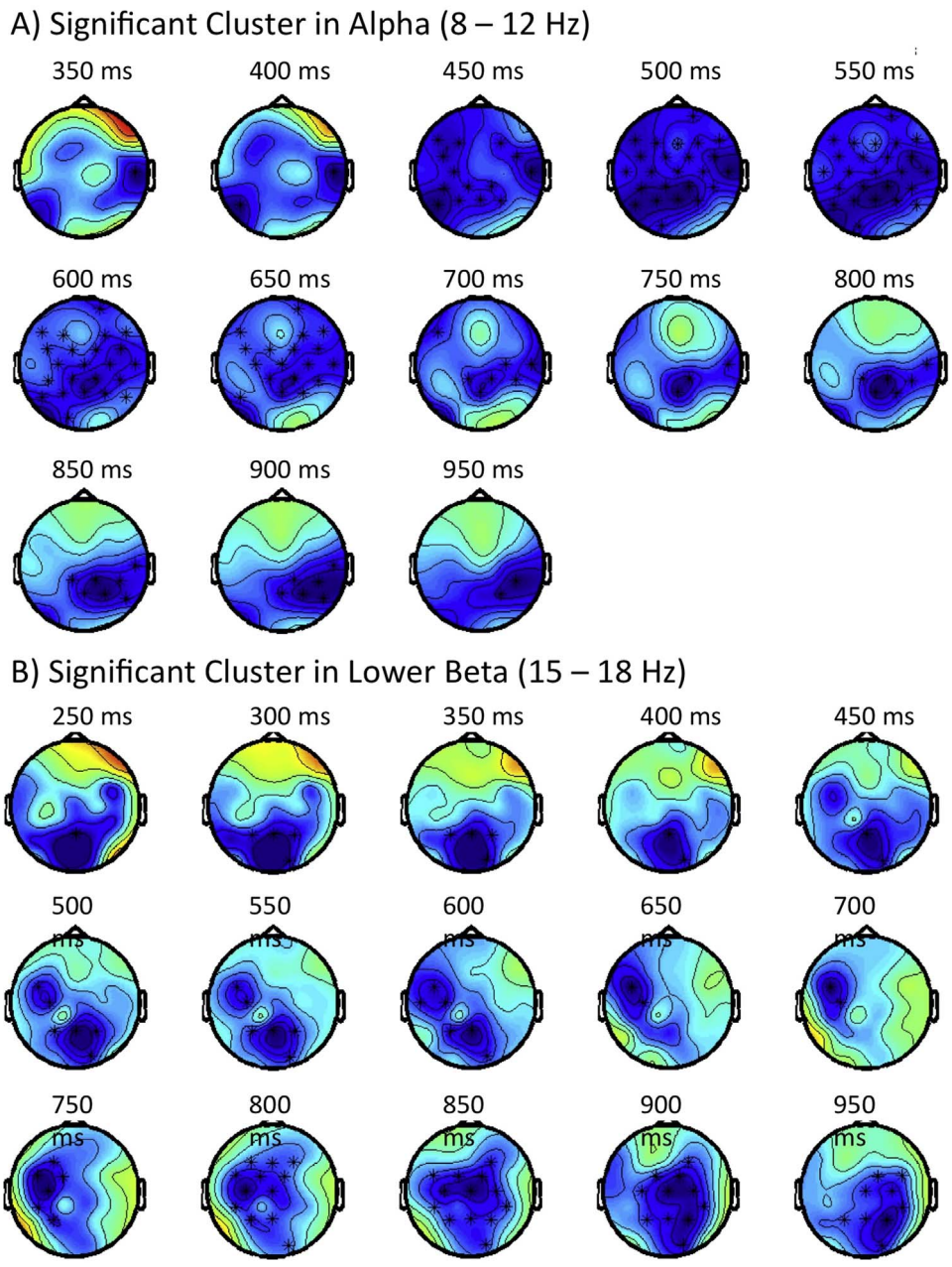

Fig. 10. Significant clusters for the interaction between DW-WW and WD-DD difference conditions. A) Power decrease in alpha band between 350 and 950 ms for DW-WW relative to WD-DD; B) Power decrease in lower beta band between 250 and 950 ms for DW-WW relative to WD-DD. Xs indicate electrodes contributing to the significant cluster.

TFR analyses of the first codeswitched word revealed an effect of codeswitching in both switching directions, but the nature of the effect differed by direction. For codeswitches into the weaker language there was a decrease in lower beta band power, while for codeswitches into the dominant language there was an increase in theta band power. Since time-frequency analysis of language research is only in its infancy, we must be cautious in interpreting TFR findings. Effects in lower beta have been associated with sentence-level binding and unification (Bastiaansen and Hagoort, 2015; Weiss and Meuller, 2012) or a change to the construction of sentence-level representations (Engel and Fries, 2010; Lewis et al., 2015), while effects in theta often are associated with lexico-semantic processing (Bakker et al., 2015; Bastiaansen and Hagoort, 2006, 2015) and word-level inhibition in language switching tasks (Liu et al., 2017).

Thus, when switching into the weaker language, both ERPs and TFRs converge to suggest that switching may engage more effortful sentence-level restructuring mechanisms (as signified by the LPC effect and a power decrease in lower beta), and TFR further revealed that switching into the dominant language appears to engage a combination of lexico-semantic and word-level inhibitory processing (as indexed by a power increase in theta).

4. General discussion

Two experiments investigated how intra-sentential codeswitches are processed in both codeswitching directions at the behavioral level (self-paced reading paradigm; Experiment 1) and the neurocognitive level (EEG; Experiment 2). The behavioral study found a somewhat larger switch cost into the dominant language than into the weaker language. To explore the nature of the neurocognitive processes underlying the comprehension of codeswitches, we conducted an EEG experiment to exploit its fine-grained temporal resolution to examine the processing that occurs before the behavioral response is realized. Two methods of analysis revealed complementary results. The

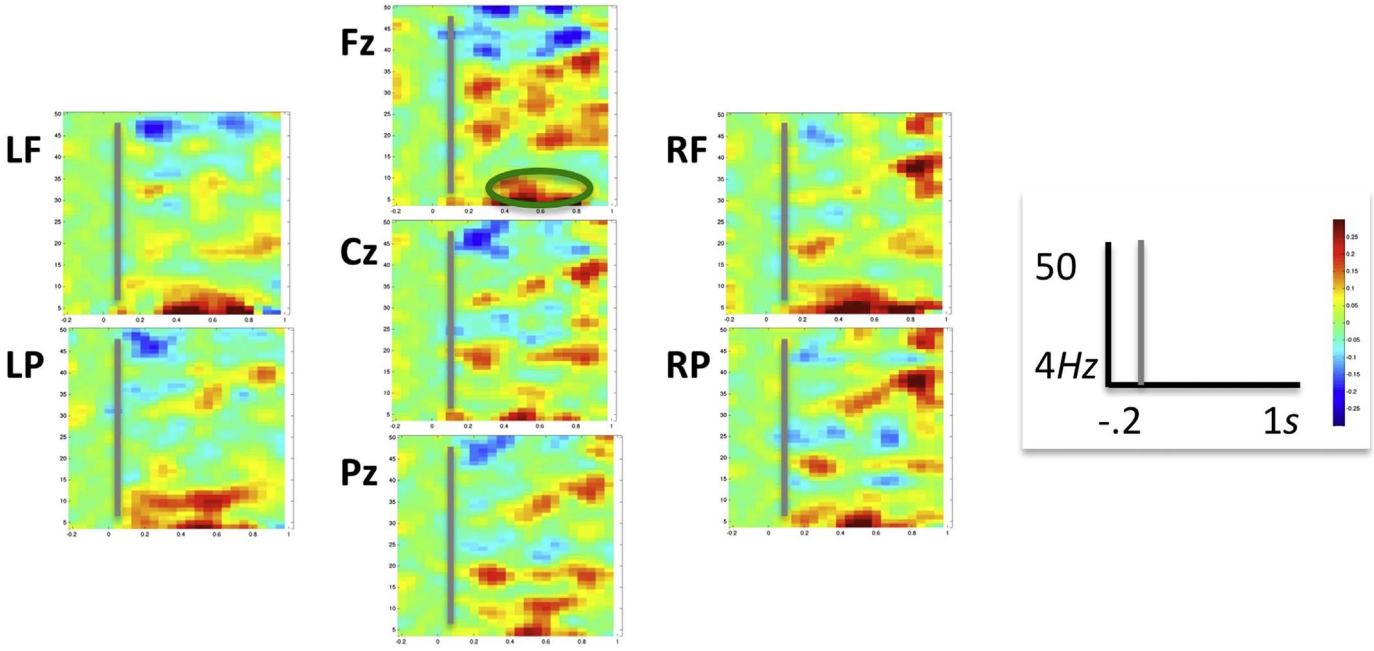

Fig. 11. TFR plots for the difference between weak to dominant codeswitches and dominant non-switches. LF=left frontal; RF=right frontal; LP=left posterior; RP=right posterior. The calibration plot shows frequency is plotted on the y-axis (4–50 Hz) and time on the x-axis (−200 to 1000 ms). Gray bar marks the onset of the critical word. Color represents power (V^2) from −.3 (blue) to .3 (red). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article).

traditional event-related potential analysis showed an asymmetry in which more effortful processing, indexed by an increased late positive component (LPC), was required when reading sentences that switch from the dominant into the weaker language, but not in the reverse direction. The ERPs suggests that bilinguals dynamically manage the relative activation of their two languages during sentence reading and that encountering an intra-sentential codeswitch into the weaker language requires sentence-level restructuring and activation of that weaker language. The time-frequency data, which reflect the complete EEG signal (in contrast to only the phase-locked information captured by ERPs), revealed a processing cost in both directions. For switches into the weaker language, a power decrease was found in lower beta, while for switches into the dominant language, a power increase was found in theta. The TFRs suggests that switches from the dominant into the weaker language signal that the extraction of the sentence-level meaning representation from the words in the dominant language requires a change in processing in order to accommodate the weaker language words (Bastiaansen and Hagoort, 2006, 2015; Lewis et al., 2015); this complements the occurrence of an LPC in the ERP signal indexing switch-related restructuring at the sentence level. For switches from the weaker to the dominant language a power increase was found in theta, suggesting that switches into the dominant language signify word-level inhibitory processing and suppression of the dominant language during weaker language processing that must be released upon encountering a codeswitch (cf., Liu et al., 2017). We will discuss processing related to each switching direction in turn. Note that we focus on switching effects with respect to participants' relative dominant and weaker language rather than L1 and L2 in order to best capture the language proficiency of our bilinguals. However, the general pattern of results was similar when data were analyzed in terms of L1 and L2.

The self-paced reading task in Experiment 1 found switching costs in both switching directions, but switching costs were larger when switching into the dominant language. This pattern is similar to production studies of isolated-item switching (Meuter and Allport, 1999), which are often interpreted as relying on inhibition of the non-target language (Green, 1998, but see Declerck and Philipp (2015) for an alternative account emphasizing that asymmetrical switching costs

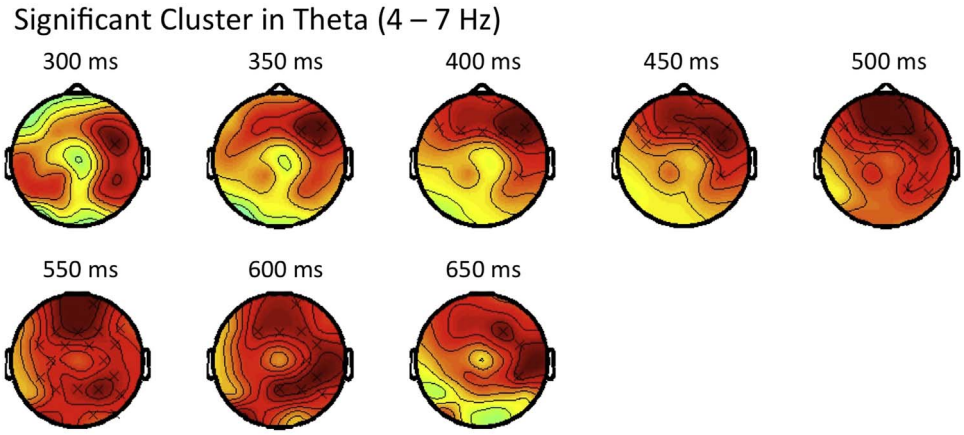

Fig. 12. Significant cluster for switches into the dominant language: A power increase in theta band between 300 and 650 ms for codeswitched words relative to non-switched words. Xs indicate electrodes contributing to the significant cluster.

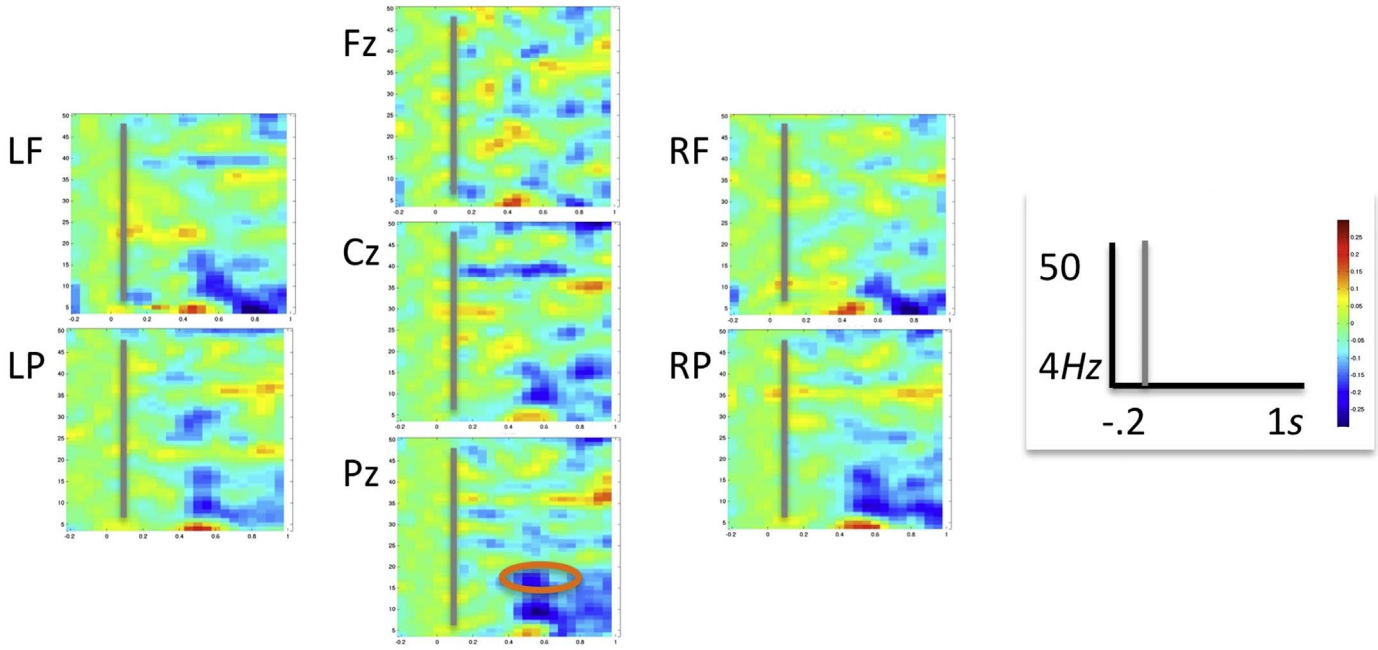

Fig. 13. TFR plots for the difference between dominant to weak codeswitches and weak non-switches. LF=left frontal; RF=right frontal; LP=left posterior; RP=right posterior. The calibration plot shows frequency is plotted on the y-axis (4–50 Hz) and time on the x-axis (−200 to 1000 ms). Gray bar marks the onset of the critical word. Color represents power (V^2) from −.3 (blue) to .3 (red). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article).

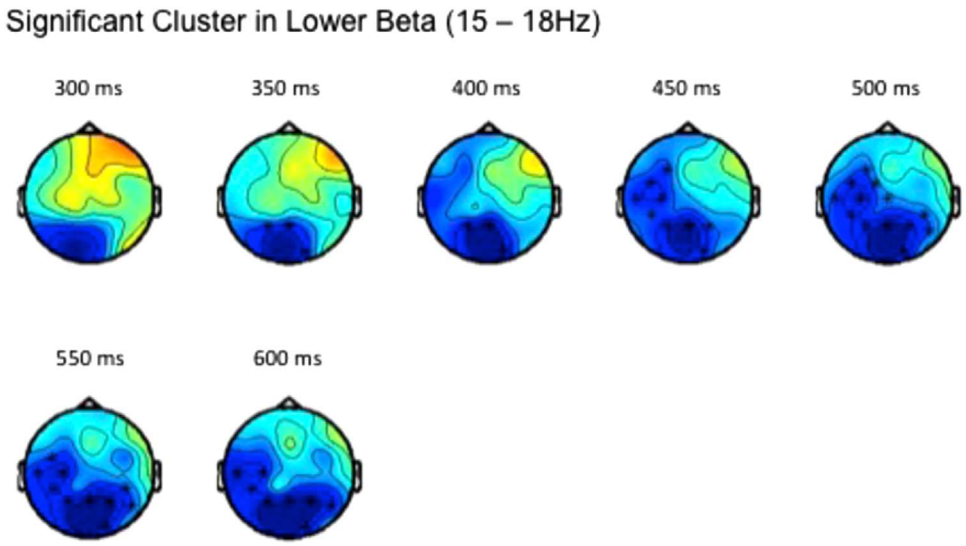

Fig. 14. Significant cluster for switches into the weaker language: A power decrease in lower beta band between 300 and 600 ms for codeswitched words relative to non-switched words. Xs mark indicates electrodes contributing to the significant cluster.

do not clearly indicate the involvement of inhibitory processing, and may also be associated with persisting activation). This suggests that while bottom-up exogenous control drives reading comprehension, the self-paced reading task additionally elicits top-down endogenous control processes due to the decision-making required by pressing a button to each word, which would result in the observed asymmetrical pattern of reading times. Moreover, this task establishes that at the end-stage of processing, intra-sentential codeswitches incur a measureable switching cost, on the basis of which we can then interpret our online electrophysiological effects as true processing costs.

Experiment 2 indicates that when bilinguals read sentences that begin in their dominant language and switch into the weaker language, they engage sentence-level restructuring mechanisms in order to activate the weaker language. ERPs found an enhanced LPC and TFRs found power decrease in lower beta for codeswitched, as compared to non-switched, words. Both of these effects are related to general sentence-level processing. During sentence reading, the bilingual is trying to extract meaning from the input and must dynamically manage the relative activation of their two languages. Because these are highly proficient bilinguals whose dominant and weaker languages reflect only a relative dominance, they should not have difficulty with lexical access and retrieval of the codeswitched word in the weaker language (see below for a related discussion of the lack of an N400 effect and the results for switching into the dominant language). Instead, the processing costs, indexed by the LPC and the power decrease in the lower beta frequency band, appear related to sentence-level restructuring mechanisms. Note that the LPC component has been observed in intra-sentential codeswitching (Moreno et al., 2002; Ng et al., 2014; Van Der Meij et al., 2011), but the LPC (P600) can also be elicited by other task manipulations such as syntactic violations in

sentences (e.g., Sassenhagen et al., 2014; Tanner et al., 2017; for reviews, see Polich, 2007; Van Petten and Luka, 2012). However, the functional interpretations of this component converge on the idea of fitting, monitoring, and linking incoming information with the previous larger structure in terms of syntax (the classic P600) or the predictability and relevance of stimuli to a given task (the classic P3). For the interpretation of the switch-related LPC we observed, we build on two recent theories of the LPC, which suggest that the LPC (or P600) reflect sentence-level restructuring (Kolk and Chwilla, 2007) or reconfiguration of the task- or language-set (Moreno et al., 2008). Kolk and Chwilla (2007) state that when there is conflict between the sentence parse and the individual word meanings or when there is a lack of information needed to continue the parse, the comprehender must reprocess to increase discourse coherence. Moreno et al.'s claim builds upon the task-switching literature and suggests that the task of reading a sentence has a given task-set, i.e., a certain language. Upon encountering the codeswitched language, this other task-set must be re-activated. Moreover, recent theories of activity in the lower beta frequency band (Bastiaansen and Hagoort, 2015; Engel and Fries, 2010; Lewis et al., 2015) suggest that it is related to syntactic unification or the ongoing building of a sentence-level meaning representation. A power decrease in low beta occurs when this ongoing process is disrupted, as in syntactic violations (Bastiaansen and Hagoort, 2015; Lewis et al., 2015), and coherence in lower beta has been associated with the processing of more complex syntactic structures such as relative clauses (Weiss et al., 2005).

Both explanations of the LPC effect rest on the difference in accessibility of a bilingual's two languages. It follows that individuals who are not fully balanced in their two languages would show a larger switch cost when switching into the weaker language since they would need to exert even more effort to activate the weaker language. Indeed, we found that the magnitude of the LPC effect was correlated with relative proficiency on the BNT and LDT tasks. Similarly, Moreno et al. (2002) found a correlation between proficiency in Spanish (the codeswitched language) and the timing and magnitude of the LPC where individuals who were less proficient in Spanish showed a later onset and larger magnitude of the LPC. These correlation analyses indicate that the switching costs found for sentences that switch from the dominant to the weaker language relate to the effortful activation of the weaker language and that codeswitching requires sentence-level restructuring in order to successfully extract meaning from the linguistic input.

For sentences that begin in the bilinguals' weaker language and switch into their dominant language, the ERP analyses yielded no significant differences between codeswitched and non-switched words, whereas TFRs found a power increase in theta. The absence of an N400 effect in this condition (in which highly proficient bilinguals made a full switch to the other language) is in contrast to previous studies of intra-sentential codeswitching, all testing insertional, lexical switches as opposed to alternational, full switches into the other language, as in the present study. These earlier studies found an N400 effect when switching from the L1 to the L2 (Moreno et al., 2002), from the L2 to the L1 (Ng et al., 2014; Van der Meij et al., 2011), and in both directions but larger into the L2 (Proverbio et al., 2004). Typically associated with lexico-semantic access and integration (e.g., Kutas and Hillyard, 1980), the N400 indicates that codeswitches present a lexical processing issue. Thus, the lack of an N400 in the current study suggests that alternational switches, as compared to lexical switches, are less likely to elicit lexico-semantic processing. Though we did not find an N400 in our codeswitched sentences, the TFRs revealed a power increase in theta, which has been associated with lexico-semantic processing in novel word-learning studies (Bakker et al., 2015) and semantic anomalies in sentences (Bastiaansen and Hagoort, 2015). However, theta effects have also been found in a single-item language switching paradigm (Liu et al., 2017) more closely aligned with the current codeswitching study. Liu et al. investigated the effect of inhibitory control and proficiency on the asymmetrical language switching finding (Meuter and Allport, 1999). Increases in theta activity were found for switches into the weaker language as compared to switches into the L1 for high-inhibitory control bilinguals. Liu et al. relate this theta activity to suppressing the non-target language while naming the switched item in the weaker language. Though the language switching paradigm of Liu et al. (2017) does not reflect true codeswitching in meaningful sentence contexts, we can extend their findings to codeswitching in which semantic and syntactic information from both languages is integrated to create complete utterances. Upon encountering a codeswitch from their weaker into the dominant language in a sentential context, bilinguals may have to release dominant-language word-level inhibition engaged during processing of their weaker language.

Overall, our results fit with the large literature on language co-activation in bilinguals and the ubiquitous finding that a bilingual's two languages interact at the lexical and sentence levels (for reviews, see Dussias et al., 2015; Van Hell and Tanner, 2012). However, the extent of this co-activation depends on the bilingual's relative proficiency in the two languages. The L1 is strongly active when processing in the weaker language L2, whereas patterns of cross-language interaction are less pronounced when processing in the dominant language L1 (e.g., Costa et al., 2000; Marian and Spivey, 2003; Van Assche et al., 2009; Van Hell and Dijkstra, 2002), and often absent in bilinguals with lower L2 proficiency levels (Van Hell and Tanner, 2012). These findings corroborate our relative proficiency explanation of the intra-sentential codeswitching data. That is, when bilinguals are processing in their dominant language, their weaker language is less strongly activated. Encountering the weaker language at the codeswitch requires sentence-level restructuring and a reconfiguration of the language set in order to fully process the codeswitched sentence, as reflected by the LPC effect and low beta power decrease. In the other switching direction, when switching from the weaker into the dominant language, the stronger dominant language possibly needs to be suppressed during weaker language sentence processing. Upon encountering a codeswitch, the switch-related theta power increase possibly points to a release of inhibition from the suppression of the dominant language during weaker language processing.

Another reason why only theta activity, but no significant N400 effect, was found for sentences that switched into the weaker language may be related to the type of codeswitch. As discussed in the Introduction, previous studies all used insertional, lexical switches where only one word was switched into the other language (Moreno et al., 2002; Ng et al., 2014; Proverbio et al., 2004; Van der Meij et al., 2011), whereas our study used alternational switches where the sentence switches into the other language and remains in that switched language. For lexical switches, the emphasis is on integrating the switched word into a sentence context entirely in the other language, and this lexical-semantic integration is reflected in the N400. Alternational switches, that better reflect how habitual Spanish-English codeswitchers naturally switch in daily conversation (Poplack, 1980), emphasize structure building across words from both languages in order to extract meaning. That lexical and alternational switches incur different types of processing aligns with, and lends support to the linguistic distinction between them based on patterns of use in corpus data (e.g., Muysken, 2000).

Finding that alternational and lexical switches incur different types of processing, namely sentence-level restructuring vs. lexico-semantic access and integration, also lends support to the adaptive control hypothesis (Green and Wei, 2014). This recent idea states that different types of codeswitches, defined as insertions (akin to lexical codeswitches), alternations, and dense codeswitching, where words and morphemes from both languages combine to form a shared language structure, require different control processes in which the two language task schemas work together either competitively, coupled, or openly. While this model focuses on production, its main idea of characterizing

the processing of codeswitches based on the type of codeswitches can be extended to comprehension wherein processing should be specific to the type of codeswitch, as seen in the current study. Moreover, its emphasis on taking into account the language environment of the speaker suggests that future research should be careful to describe the type of codeswitches used in the experiment as well as the type of codeswitches typically produced by the participants in natural speech. Results may differ when there is congruence between the stimuli and the typical codeswitching behavior and when there is conflict. In the present study we tested bilinguals who codeswitch in their daily lives. For non-habitual codeswitchers, the adaptive control hypothesis suggests that they should experience larger processing costs than habitual codeswitchers when encountering intra-sentential codeswitches, because alternational codeswitching contrasts with the non-habitual codeswitchers' usual mode of language use, in which they keep their languages separate or use occasional insertional codeswitches (for a more detailed discussion, see Guzzardo et al. (2016) and Van Hell et al. (2015)).

In conclusion, we examined the behavioral and neurocognitive response to intra-sentential codeswitches in highly proficient bilinguals and how the direction of the codeswitch affects processing. At the end stage of processing (indexed by reaction time measures), codeswitches incur a behavioral processing cost that is somewhat larger into the dominant than into the weaker language. EEG data, i.e. ERP and TFR analyses, yielded complementary findings, and show that the nature of the online neural processing differs for the two switching directions, which appears to be a function of relative language proficiency. ERPs revealed an effect of switching only into the weaker language related to sentence-level restructuring mechanisms and relative proficiency in the two languages. TFRs revealed an effect in both codeswitching directions: they corroborate the ERP data by suggesting that switching into the weaker language relates to a change to the construction of sentence-level meaning representations, requiring sentence-level restructuring mechanisms, while they suggest that costs for switching into the dominant language relate to word-level inhibitory processing associated with suppression of the dominant language prior to the switch. These combined results suggest that in sentence comprehension, bilinguals continuously adjust the relative activation of their two languages and that upon encountering a codeswitch into the weaker language, sentence-level restructuring processes are recruited to activate and access the weaker language, and that upon encountering a codeswitch into the dominant language, word-level inhibition of the dominant language during processing in the weaker language must be released. These results also underscore the need for a multi-method approach to the processing of codeswitches to capture the online and end point of processing, as well as different neurocognitive mechanisms that drive online comprehension of codeswitched sentences.

Acknowledgements

We would like to thank Maria Allyon, Brandon Beachum, Allyson Carmona, Kevin Donley, Paige Elinsky, Gabrielle Fridman, Alejandra Rodriguez, and Kaylee Roupas for help with stimuli creation, data collection, and coding. We would also like to thank Darren Tanner for helpful comments and Tim Poepsel for help with data processing. This work was supported by funding from National Science Foundation Grants OISE-0968369 and BCS-1349110 to Janet G. Van Hell, and a Pennsylvania State University Graduate Fellowship to Kaitlyn A. Litcofsky.

Appendix

Conditions: 1) English→Spanish Codeswitch; 2) English No Codeswitch; 3) Spanish→English Codeswitch; 4) Spanish No Codeswitch

Condition	Sentence
1	This morning, a wild vulture bit a conejo que pasaba corriendo muy rápido.
2	This morning, a wild vulture bit a rabbit who ran past very quickly.
3	Esta mañana, un buitre salvaje mordió a un rabbit who ran past very quickly.
4	Esta mañana, un buitre salvaje mordió a un conejo que pasaba corriendo muy rápido.
1	After the felony, a harsh punishment was given to the ladrones por el juez.
2	After the felony, a harsh punishment was given to the thieves by the judge.
3	Después del delito, un duro castigo les fue dado a los thieves by the judge.
4	Después del delito, un duro castigo les fue dado a los ladrones por el juez.
1	The girl saw some nice shirts in the tienda frente a su escuela.
2	The girl saw some nice shirts in the shop across the street from her school.
3	La niña vio unas camisas bonitas en el shop across the street from her school.
4	La niña vio unas camisas bonitas en la tienda frente a su escuela.
1	Every Sunday, she reads a short book related to ajedrez para mejorar sus habilidades.
2	Every Sunday, she reads a short book related to chess to improve her skills.
3	Todos los domingos, ella lee un libro corto sobre el chess to improve her skills.
4	Todos los domingos, ella lee un libro corto sobre el ajedrez para mejorar sus habilidades.
1	A lot of brochures were handed out by the manifestantes antes de su protesta.
2	A lot of brochures were handed out by the protesters before their rally.
3	Un montón de folletos fueron repartidos por los protesters before their rally.
4	Un montón de folletos fueron repartidos por los manifestantes antes de su protesta.
1	Next week, the young waiter will begin his trabajo con gran entusiasmo.
2	Next week, the young waiter will begin his job with great excitement.
3	La semana próxima, el camarero joven comenzará su job with great excitement.
4	La semana próxima, el camarero joven comenzará su trabajo con gran entusiasmo.
1	The old men got together to watch a movie about the pandillas en su ciudad.
2	The old men got together to watch a movie about the gangs in their city.

3 Los ancianos se reunieron para ver una película sobre los gangs in their city.
4 Los ancianos se reunieron para ver una película sobre las pandillas en su ciudad.
1 In its basement, the building collects hundreds of maletas perdidas de diversos visitantes.
2 In its basement, the building collects hundreds of suitcases lost by the various visitors.
3 En su sótano, el edificio guarda cientos de suitcases lost by the various visitors.
4 En su sótano, el edificio guarda cientos de maletas perdidas de diversos visitantes.
1 The other night, the neighbors watched the lucha pero no trataron de detenerla.
2 The other night, the neighbors watched the fight but did not try to stop it.
3 La otra noche, los vecinos miraron el fight but did not try to stop it.
4 La otra noche, los vecinos miraron la lucha pero no trataron de detenerla.
1 Tomorrow, Aaron and his friends will build some escudos para usar en un juego de rol.
2 Tomorrow, Aaron and his friends will build some shields to use in a fantasy game.
3 Mañana, Aarón y sus amigos construirán unos shields to use in a fantasy game.
4 Mañana, Aarón y sus amigos construirán unos escudos para usar en un juego de rol.
1 Very angrily, the businessman pounded on his teclado para quitarse el estrés.
2 Very angrily, the businessman pounded on his keyboard to get rid of stress.
3 Muy enojado, el empresario golpeó su keyboard to get rid of stress.
4 Muy enojado, el empresario golpeó su teclado para quitarse el estrés.
1 He is best known as a writer of an assortment of cuentos y poesía hermosa.
2 He is best known as a writer of an assortment of stories and beautiful poetry.
3 Él es más conocido como escritor de un surtido de stories and beautiful poetry.
4 Él es más conocido como escritor de un surtido de cuentos y poesía hermosa.
1 While running her errands, the consultant stopped at the quiosco a recoger el periódico de hoy.
2 While running her errands, the consultant stopped at the newsstand to pick up today's paper.
3 Mientras hacía sus mandados, la asesora se detuvo en el newsstand to pick up today's paper.
4 Mientras hacía sus mandados, la asesora se detuvo en el quiosco a recoger el periódico de hoy.
1 She was on her way to a parade with a cantante a quien había admirado durante mucho tiempo.
2 She was on her way to a parade with a singer whom she had admired for a long time.
3 Ella se dirigía a un desfile con un singer whom she had admired for a long time.
4 Ella se dirigía a un desfile con un cantante a quien había admirado durante mucho tiempo.
1 Even though it was a dreary day, Ann's friendly parrot ensured a sonrisa en el público.
2 Even though it was a dreary day, Ann's friendly parrot ensured a smile with the audience.
3 A pesar de que era un día gris, el amigable loro de Ana aseguró un smile with the audience.
4 A pesar de que era un día gris, el amigable loro de Ana aseguró una sonrisa en el público.
1 Christina was uneasy because of the dogs spotted around the vecindario a principios de esta semana.
2 Christina was uneasy because of the dogs spotted around the neighborhood earlier this week.
3 Cristina estaba inquieta a causa de los perros encontrados en el neighborhood earlier this week.
4 Cristina estaba inquieta a causa de los perros encontrados en el vecindario a principios de esta semana.
1 Everyone at the party whispered about the cintas que decoraban toda la habitación.
2 Everyone at the party whispered about the ribbons that decorated the entire room.
3 Todos en la fiesta susurraban sobre los ribbons that decorated the entire room.
4 Todos en la fiesta susurraban sobre las cintas que decoraban toda la habitación.
1 Arthur hoped that the gift would not be filled with calcetines y corbatas feas.
2 Arthur hoped that the gift would not be filled with socks and ugly ties.
3 Arthur esperaba que el regalo no estuviera lleno de socks and ugly ties.
4 Arthur esperaba que el regalo no estuviera lleno de calcetines y corbatas feas.
1 Please put the extra meat in the congelador cuando termines de comer.
2 Please put the extra meat in the freezer when you are done eating.
3 Por favor, pon la carne sobrante en el freezer when you are done eating.
4 Por favor, pon la carne sobrante en el congelador cuando termines de comer.
1 Yesterday, George found out that a jail will replace the bodega que fue demolida el año pasado.
2 Yesterday, George found out that a jail will replace the warehouse that was demolished last year.
3 Ayer, Jorge descubrió que una cárcel reemplazará al warehouse that was demolished last year.
4 Ayer, Jorge descubrió que una cárcel reemplazará a la bodega que fue demolida el año pasado.
1 Every morning, Sarah gets her gloves caught in the cremallera de su chaqueta.
2 Every morning, Sarah gets her gloves caught in the zipper of her jacket.
3 Cada mañana, a Sara se le enganchan los guantes en el zipper of her jacket.
4 Cada mañana, a Sara se le enganchan los guantes en la cremallera de su chaqueta.
1 Suddenly, I remembered that the woman had warned us about the tempestad que se avecinaba.
2 Suddenly, I remembered that the woman had warned us about the storm that was coming.
3 De repente, me acordé de que la mujer nos había advertido sobre el storm that was coming.
4 De repente, me acordé de que la mujer nos había advertido sobre la tempestad que se avecinaba.
1 Sadly, the young winner sprained his tobillo y no pudo competir en la ronda final.
2 Sadly, the young winner sprained his ankle and could no longer compete in the final round.
3 Tristamente, el joven ganador se torció el ankle and could no longer compete in the final round.
4 Tristamente, el joven ganador se torció el tobillo y no pudo competir en la ronda final.

1 Last week, a truck overturned in the carretera y derramó muchos litros de combustible.
2 Last week, a truck overturned in the road and spilled many gallons of fuel.
3 La semana pasada, un camión volcó en el road and spilled many gallons of fuel.
4 La semana pasada, un camión volcó en la carretera y derramó muchos litros de combustible.
1 Staring into the sky, the dreamer thought about his esperanzas y sueños para el futuro.
2 Staring into the sky, the dreamer thought about his hopes and dreams for the future.
3 Mirando al cielo, el soñador pensaba en sus hopes and dreams for the future.
4 Mirando al cielo, el soñador pensaba en sus esperanzas y sueños para el futuro.
1 For the winter, Angela's scarf was made out of lana para mantenerla caliente.
2 For the winter, Angela's scarf was made out of wool to keep her warm.
3 Para el invierno, la bufanda de Angela fue hecha de wool to keep her warm.
4 Para el invierno, la bufanda de Angela fue hecha de lana para mantenerla caliente.
1 This morning, the orderly brought the muletas a Ana y le mostró cómo usarlas.
2 This morning, the orderly brought the crutches to Anne and showed her how to use them.
3 Esta mañana, el camillero le trajo los crutches to Anne and showed her how to use them.
4 Esta mañana, el camillero le trajo las muletas a Ana y le mostró cómo usarlas.
1 Last year, the earthquake destroyed all of the aldea y sus alrededores.
2 Last year, the earthquake destroyed all of the village and the surrounding areas.
3 El año pasado, el terremoto destruyó todo el village and the surrounding areas.
4 El año pasado, el terremoto destruyó toda la aldea y sus alrededores.
1 For tomorrow, bring an eraser for the prueba de física y astronomía.
2 For tomorrow, bring an eraser for the quiz on physics and astronomy.
3 Para mañana, trae una goma para el quiz on physics and astronomy.
4 Para mañana, trae una goma para la prueba de física y astronomía.
1 The other night, the rooster wandered into a prado que era muy peligroso.
2 The other night, the rooster wandered into a meadow that was very dangerous.
3 La otra noche, el gallo vagó en un meadow that was very dangerous.
4 La otra noche, el gallo vagó en un prado que era muy peligroso.
1 Looking over the crowd, the supporter stood atop of the escaleras y gritó su oposición.
2 Looking over the crowd, the supporter stood atop of the stairs and shouted his opposition.
3 Mirando sobre la gente, el partidario se paró encima de los stairs and shouted his opposition.
4 Mirando sobre la gente, el partidario se paró encima de las escaleras y gritó su oposición.
1 Adam wanted to pick peaches and lots of ciruelas en la granja cercana.
2 Adam wanted to pick peaches and lots of plums at the nearby farm.
3 Adán quería recoger melocotones y un montón de plums at the nearby farm.
4 Adán quería recoger melocotones y un montón de ciruelas en la granja cercana.
1 Being lazy, the boys threw stones into the estanque para pasar el tiempo.
2 Being lazy, the boys threw stones into the pond to pass the time.
3 Con pereza, los chicos tiraron piedras en el pond to pass the time.
4 Con pereza, los chicos tiraron piedras en el estanque para pasar el tiempo.
1 Some people at the beach watch all the peces nadando entre los corales.
2 Some people at the beach watch all the fish swimming amongst the coral.
3 Alguna gente en la playa ve todos los fish swimming amongst the coral.
4 Alguna gente en la playa ve todos los peces nadando entre los corales.
1 Once a month, referees mingle with the jugadores antes de que empiece el juego.
2 Once a month, referees mingle with the players before the game starts.
3 Una vez al mes, los árbitros se entremezclan con los playes before the game starts.
4 Una vez al mes, los árbitros se entremezclan con los jugadores antes de que empiece el juego.
1 Sometimes, young people enjoy eating grapes during a descanso de sus clases.
2 Sometimes, young people enjoy eating grapes during a break from their classes.
3 A veces, los jóvenes disfrutan comiendo uvas durante el break from their classes.
4 A veces, los jóvenes disfrutan comiendo uvas durante el descanso de sus clases.
1 Elizabeth brought her granddaughter on a caminata a lo largo del río.
2 Elizabeth brought her granddaughter on a walk along the river.
3 Elena llevó a su nieta en un walk along the river.
4 Elena llevó a su nieta en una caminata a lo largo del río.
1 In the fall, some people put skulls in the ventanas de sus casas.
2 In the fall, some people put skulls in the windows of their houses.
3 En el otoño, la gente pone calaveras en los windows of their houses.
4 En el otoño, la gente pone calaveras en las ventanas de sus casas.
1 After the couple's wedding, their church was covered in carteles, guirnaldas y globos.
2 After the couple's wedding, their church was covered in posters, streamers, and balloons.
3 Después de la boda de la pareja, su iglesia estaba cubierta de posters, streamers, and balloons.
4 Después de la boda de la pareja, su iglesia estaba cubierta de carteles, guirnaldas y globos.
1 Since Danielle was homesick, her boyfriend bought her a boleto para volver de visita.
2 Since Danielle was homesick, her boyfriend bought her a ticket to come visit.

3 Dado que Daniela añoraba su casa, su novio le compró un ticket to come visit.
4 Dado que Daniela añoraba su casa, su novio le compró un boleto para volver de visita.
1 Charlie will soon be a lawyer with his own velero como su padre.
2 Charlie will soon be a lawyer with his own sailboat just like his father.
3 Carlos pronto será un abogado con su propio sailboat just like his father.
4 Carlos pronto será un abogado con su propio velero como su padre.
1 At last, the squad saw the preso cuando salía de su casa.
2 At last, the squad saw the inmate as he left his house.
3 Por fin, la cuadrilla vio al inmate as he left his house.
4 Por fin, la cuadrilla vio al preso cuando salía de su casa.
1 Thankfully, the ignited skyscraper was saved by the bomberos que fueron muy valientes.
2 Thankfully, the ignited skyscraper was saved by the firemen who are very brave.
3 Con agradecimiento, el rascacielos incendiado se salvó por los firemen who are very brave.
4 Con agradecimiento, el rascacielos incendiado se salvó por los bomberos que fueron muy valientes.
1 People say that childhood brings some of the best recuerdos de la vida.
2 People say that childhood brings some of the best memories of your life.
3 La gente dice que la niñez trae algunos de los mejores memories of your life.
4 La gente dice que la niñez trae algunos de los mejores recuerdos de la vida.
1 The woman at the tombstone bowed her cabeza para rezar en silencio.
2 The woman at the tombstone bowed her head to pray in silence.
3 La mujer en la lápida bajó su head to pray in silence.
4 La mujer en la lápida bajó su cabeza para rezar en silencio.
1 She likes to watch the sparrows rather than the patos que viven cerca del embalse.
2 She likes to watch the sparrows rather than the ducks that live near the reservoir.
3 Le gusta ver los gorriones en vez de los ducks that live near the reservoir.
4 Le gusta ver los gorriones en vez de los patos que viven cerca del embalse.
1 The stove was leaking smoke into the entire cocina y se incendió.
2 The stove was leaking smoke into the entire kitchen and caught on fire.
3 La estufa emanaba humo en todo el kitchen and caught on fire.
4 La estufa emanaba humo en toda la cocina y se incendió.
1 The dust rose off of the sidewalk in lots of remolinos de calor y suciedad.
2 The dust rose off of the sidewalk in lots of swirls of heat and dirt.
3 El polvo se levantó fuera de la acera en un montón de swirls of heat and dirt.
4 El polvo se levantó fuera de la acera en un montón de remolinos de calor y suciedad.
1 Emilie and her aunt love apple dumplings served with nueces en el lado.
2 Emilie and her aunt love apple dumplings served with walnuts on the side.
3 Carolina y su tía aman los bollos de manzana servidos con walnuts on the side.
4 Carolina y su tía aman los bollos de manzana servidos con nueces en el lado.
1 Her expansive and beautiful lawn was covered with faroles y gnomos de jardín.
2 Her expansive and beautiful lawn was covered with lanterns and garden gnomes.
3 Su amplio y hermoso césped estaba cubierto con lanterns and garden gnomes.
4 Su amplio y hermoso césped estaba cubierto con faroles y gnomos de jardín.
1 The king instructed that his blade be made of oro y de bronce solamente.
2 The king instructed that his blade be made of gold and bronze only.
3 El rey ordenó que su hoja fuera de gold and bronze only.
4 El rey ordenó que su hoja fuera de oro y de bronce solamente.
1 He decided to become a clergyman after the muerte de su abuelo.
2 He decided to become a clergyman after the death of his grandfather.
3 Él eligió ser sacerdote después del death of his grandfather.
4 Él eligió ser sacerdote después de la muerte de su abuelo.
1 Even though her review was turned down by the revista, ella la publicó independientemente.
2 Even though her review was turned down by the journal, she published it independently.
3 A pesar de que su reseña fue rechazada por el journal, she published it independently.
4 A pesar de que su reseña fue rechazada por la revista, ella la publicó independientemente.
1 Brittney cleaned up the counter with a trapo después del enorme derrame.
2 Brittney cleaned up the counter with a rag after the huge spill.
3 Bibiana limpió el mostrador con un rag after the huge spill.
4 Bibiana limpió el mostrador con un trapo después del enorme derrame.
1 She brought her umbrella along with her gabardina para mantenerse seca de la fuerte lluvia.
2 She brought her umbrella along with her raincoat to keep her dry from the heavy rain.
3 Ella trajo su paraguas junto con su raincoat to keep her dry from the heavy rain.
4 Ella trajo su paraguas junto con su gabardina para mantenerse seca de la fuerte lluvia.
1 Sophia lounged around in her slippers with a resfriado mientras estaba encerrada en su casa.
2 Sophia lounged around in her slippers with a cold while she was stuck at her house.
3 Sofía holgazaneó en sus pantuflas con un cold while she was stuck at her house.
4 Sofía holgazaneó en sus pantuflas con un resfriado mientras estaba encerrada en su casa.

1 Paul asked to see the ring in the vitrina de la joyería.
2 Paul asked to see the ring in the showcase at the jewelry store.
3 Pablo pidió ver el anillo en el showcase at the jewelry store.
4 Pablo pidió ver el anillo en la vitrina de la joyería.
1 Roger took the overcoat to his sastre para hacer alteraciones.
2 Roger took the overcoat to his tailor to get alterations.
3 Rodrigo llevó el abrigo a su tailor to get alterations.
4 Rodrigo llevó el abrigo a su sastre para hacer alteraciones.
1 Nicholas bought some ointment for the ampolla en su mano.
2 Nicholas bought some ointment for the blister on his hand.
3 Nicolás compró una pomada para el blister on his hand.
4 Nicolás compró una pomada para la ampolla en su mano.
1 Luckily, Victoria had no wounds except a sarpullido que preocupó a los paramédicos.
2 Luckily, Victoria had no wounds except a rash that worried the paramedics.
3 Por suerte, Victoria no tuvo heridas salvo un rash that worried the paramedics.
4 Por suerte, Victoria no tuvo heridas salvo un sarpullido que preocupó a los paramédicos.
1 Jessica will learn more about her midwife during a cita la próxima semana.
2 Jessica will learn more about her midwife during an appointment in the next few weeks.
3 Jessenia va a saber más sobre su comadrona durante un appointment in the next few weeks.
4 Jessenia va a saber más sobre su comadrona durante una cita la próxima semana.
1 She did her homework on the birth of the estrellas según como se ven en varios países.
2 She did her homework on the birth of the stars as seen from various countries.
3 Ella hizo su tarea sobre el nacimiento de los stars as seen from various countries.
4 Ella hizo su tarea sobre el nacimiento de las estrellas según como se ven en varios países.
1 Filled with anger, the knight slayed the bruja en la torre.
2 Filled with anger, the knight slayed the witch in the high tower.
3 Lleno de enojo, el caballero mató al witch in the high tower.
4 Lleno de enojo, el caballero mató a la bruja en la torre.
1 Out of sympathy, the traveler told the mendigo dónde encontrar ayuda.
2 Out of sympathy, the traveler told the beggar where to find some help.
3 Por lástima, el viajero le dijo al beggar where to find some help.
4 Por lástima, el viajero le dijo al mendigo dónde encontrar ayuda.
1 They found out that the nurse liked her jefe por su generosidad.
2 They found out that the nurse liked her boss because of his generosity.
3 Ellos se enteraron de que a la enfermera le gustaba su boss because of his generosity.
4 Ellos se enteraron de que a la enfermera le gustaba su jefe por su generosidad.
1 I think that puppies are scared of aspiradoras porque hacen mucho ruido.
2 I think that puppies are scared of vacuums because they are loud.
3 Creo que los cachorros tienen miedo de los vacuums because they are loud.
4 Creo que los cachorros tienen miedo de las aspiradoras porque hacen mucho ruido.
1 From what I've noticed, wasps often hate abejas con una pasión violenta.
2 From what I've noticed, wasps often hate bees with a violent passion.
3 Por lo que he notado, las avispas a menudo odian a los bees with a violent passion.
4 Por lo que he notado, las avispas a menudo odian a las abejas con una pasión violenta.
1 In the old days, planes had fewer asientos, pero había más lujos.
2 In the old days, planes had fewer seats, but had more luxuries.
3 En los viejos tiempos, los aviones tenían menos seats, but had more luxuries.
4 En los viejos tiempos, los aviones tenían menos asientos, pero había más lujos.
1 Eleanor could not believe the wickedness and sadness of the hambruna que ocurría por todo el lugar.
2 Eleanor could not believe the wickedness and sadness of the famine occuring all over the place.
3 Eleanor no podía creer la maldad y tristeza del famine occuring all over the place.
4 Eleanor no podía creer la maldad y tristeza de la hambruna que ocurría por todo el lugar.
1 The girl set the notebook on the mesa con la intención de finalmente comenzar su investigación.
2 The girl set the notebook on the table with the intent of finally starting her research.
3 La niña dejó el cuaderno sobre el table with the intent of finally starting her research.
4 La niña dejó el cuaderno sobre la mesa con la intención de finalmente comenzar su investigación.
1 After seeing Molly's distress from the broma, Franco se arrepintió de haberla planeado.
2 After seeing Molly's distress from the prank, Frank regretted planning it.
3 Después de ver la angustia de Amelia por el prank, Frank regretted planning it.
4 Después de ver la angustia de Amelia por la broma, Franco se arrepintió de haberla planeado.
1 When Nathan is sick, he pours some honey into his leche para sentirse mejor.
2 When Nathan is sick, he pours some honey into his milk to feel better.
3 Cuando Alberto está enfermo, él echa un poco de miel en su milk para to feel better.
4 Cuando Alberto está enfermo, él echa un poco de miel en su leche para sentirse mejor.
1 Scott likes playing basketball instead of esgrima para mantenerse en forma.
2 Scott likes playing basketball instead of fencing in order to stay in shape.

3 A Sergio le gusta jugar al baloncesto en lugar de hacer fencing in order to stay in shape.
4 A Sergio le gusta jugar al baloncesto en lugar de hacer esgrima para mantenerse en forma.
1 This morning, the manager received the impresora de la oficina principal.
2 This morning, the manager received the printer from the main office.
3 Esta mañana, el gerente recibió el printer from the main office.
4 Esta mañana, el gerente recibió la impresora de la oficina principal.
1 Soon after arriving, the stewardess found her equipaje y se dirigió al coche.
2 Soon after arriving, the stewardess found her luggage and headed to the car.
3 A poco de llegar, la azafata encontró su luggage and headed to the car.
4 A poco de llegar, la azafata encontró su equipaje y se dirigió al coche.
1 That morning, the lifeguards watched the ola cuando llegaba a la costa.
2 That morning, the lifeguards watched the wave as it hit the shore.
3 Essa mañana, los salvavidas vieron el wave as it hit the shore.
4 Essa mañana, los salvavidas vieron la ola cuando llegaba a la costa.
1 Last week, Marcus hung a clock next to the espejo en su habitación.
2 Last week, Marcus hung a clock next to the mirror in his room.
3 La semana pasada, Manuel colgó un reloj al lado del mirror in his room.
4 La semana pasada, Manuel colgó un reloj al lado del espejo en su habitación.
1 Yesterday we agreed that the striped pillows match the alfombra en la sala de estar.
2 Yesterday we agreed that the striped pillows match the rug in the living room.
3 Ayer acordamos que las almohadas de rayas coinciden con el rug in the living room.
4 Ayer acordamos que las almohadas de rayas coinciden con la alfombra en la sala de estar.
1 Bryan will spend a week at the wharf as part of a viaje con su compañía.
2 Bryan will spend a week at the wharf as part of a trip with his company.
3 Armando pasará una semana en el embarcadero como parte de un trip with his company.
4 Armando pasará una semana en el embarcadero como parte de un viaje con su compañía.
1 All summer long, Chris collected spiders and other muestras para examinar en su microscopio nuevo.
2 All summer long, Chris collected spiders and other specimens to view under his new microscope.
3 Todo el verano, Lucas recogió arañas y otros specimens para to view under his new microscope.
4 Todo el verano, Lucas recogió arañas y otros muestras para examinar en su microscopio nuevo.
1 Luckily for me, the hairdresser can cut any cabello en los últimos estilos.
2 Luckily for me, the hairdresser can cut any hair in the latest styles.
3 Por suerte para mí, el peluquero puede cortar cualquier hair in the latest styles.
4 Por suerte para mí, el peluquero puede cortar cualquier cabello en los últimos estilos.
1 Feeling very tired, the baker took a siesta para recuperar su energía.
2 Feeling very tired, the baker took a nap to boost his energy.
3 Sintiéndose muy cansado, el panadero tomó un nap to boost his energy.
4 Sintiéndose muy cansado, el panadero tomó una siesta para recuperar su energía.
1 When night fell, the wolf howled at the luna lo más fuerte que pudo.
2 When night fell, the wolf howled at the moon as loudly as he could.
3 Al caer la noche, el lobo aulló al moon as loudly as he could.
4 Al caer la noche, el lobo aulló a la luna lo más fuerte que pudo.
1 I enjoy eating cinnamon with my desayuno porque es saludable.
2 I enjoy eating cinnamon with my breakfast because it is healthy.
3 Me gusta comer canela con el breakfast because it is healthy.
4 Me gusta comer canela con el desayuno porque es saludable.
1 Having learned that beetles have so many patas y pueden morder, Gloria les tiene miedo.
2 Having learned that beetles have so many legs and can bite, Gloria is now very scared of them.
3 Al enterarse de que los escarabajos tienen tantos legs and can bite, Gloria is now very scared of them.
4 Al enterarse de que los escarabajos tienen tantas patas y pueden morder, Gloria les tiene miedo.
1 They could not carry the mattress through the small puerta de la casa de la pareja.
2 They could not carry the mattress through the small door of the couple's house.
3 Ellos no podían llevar el colchón a través del pequeño door of the couple's house.
4 Ellos no podían llevar el colchón a través de la pequeña puerta de la casa de la pareja.
1 She hung her dresses on the tendedero y se le volaron todos.
2 She hung her dresses on the clothesline and they all blew away.
3 Ella colgó sus vestidos en el clothesline and they all blew away.
4 Ella colgó sus vestidos en el tendedero y se le volaron todos.
1 The cat chased the squirrel through the entire alcantarilla hasta que finalmente la atrapó.
2 The cat chased the squirrel through the entire sewer until he finally caught it.
3 El gato persiguió a la ardilla por toda el sewer until he finally caught it.
4 El gato persiguió a la ardilla por toda la alcantarilla hasta que finalmente la atrapó.
1 He hoped that the pills could cure his caballo enfermo antes del concurso la semana siguiente.
2 He hoped that the pills could cure his sick horse before the show the following week.
3 Él esperaba que las pastillas pudieran curar a su horse before the show the following week.
4 Él esperaba que las pastillas pudieran curar a su caballo enfermo antes del concurso la semana siguiente.

1 Madeline wrote some folktales about two palomas, los símbolos de la paz y el amor.
2 Madeline wrote some folktales about two doves, the symbols of peace and love.
3 Marcela escribió algunas leyendas sobre dos doves, the symbols of peace and love.
4 Marcela escribió algunas leyendas sobre dos palomas, los símbolos de la paz y el amor.
1 Tyler will only eat noodles with butter and repollo desde que él concoció la comida polaca.
2 Tyler will only eat noodles with butter and cabbage ever since he was introduced to Polish cuisine.
3 Tito sólo come fideos con mantequilla y cabbage ever since he was introduced to Polish cuisine.
4 Tito sólo come fideos con mantequilla y repollo desde que él concoció la comida polaca.
1 After the blizzard, helpers provided some alivio a las víctimas.
2 After the blizzard, helpers provided some relief for the victims.
3 Después de la ventisca, ayudantes proporcionaron algo de relief for the victims.
4 Después de la ventisca, ayudantes proporcionaron algo de alivio a las víctimas.
1 Kristy loves to have ferns in her hogar porque traen buena suerte.
2 Kristy loves to have ferns in her home because they bring her good luck.
3 A Celia le encanta tener helechos en su home because they bring her good luck.
4 A Celia le encanta tener helechos en su hogar porque traen buena suerte.
1 Very repulsed, the shopper removed all the anacardos de su ensalada.
2 Very repulsed, the shopper removed all the cashews from his salad.
3 Muy asqueado, el parroquiano quitó todos los cashews from his salad.
4 Muy asqueado, el parroquiano quitó todos los anacardos de su ensalada.
1 On the hill there is a nursery where the monjas honran su virtud.
2 On the hill there is a nursery where the nuns honor their virtue.
3 En la colina hay una guardería donde los nuns honor their virtue.
4 En la colina hay una guardería donde las monjas honran su virtud.
1 I like eating chicken with a side of papitas y un batido.
2 I like eating chicken with a side of fries and a milkshake.
3 Me gusta comer pollo con una guarnición de fries and a milkshake.
4 Me gusta comer pollo con una guarnición de papitas y un batido.
1 Tori and Jess went to a dance for the becarios que vienen de Europa.
2 Tori and Jess went to a dance for the scholars visiting from Europe.
3 Tonya y Josefina fueron a un baile para los scholars visiting from Europe.
4 Tonya y Josefina fueron a un baile para los becarios que vienen de Europa.
1 Alexa stuffed a bunch of coins into her bolsillo antes de ir al supermercado.
2 Alexa stuffed a bunch of coins into her pocket before heading to the supermarket.
3 Alejandra metió un montón de monedas en su pocket before heading to the supermarket.
4 Alejandra metió un montón de monedas en su bolsillo antes de ir al supermercado.
1 According to Peter, no brewery will provide a cena tan tarde por la noche.
2 According to Peter, no brewery will provide a meal so late at night.
3 Según Pedro, ninguna cervecería servirá un meal so late at night.
4 Según Pedro, ninguna cervecería servirá una cena tan tarde por la noche.
1 This morning, they approved the budget for this primavera después de muchas reuniones.
2 This morning, they approved the budget for this spring after many meetings.
3 Esta mañana, ellos aprobaron el presupuesto para este spring after many meetings.
4 Esta mañana, ellos aprobaron el presupuesto para esta primavera después de muchas reuniones.
1 Early this morning, the board acknowledged their elogios por el comportamiento de los aficionados durante el partido del campeonato.
2 Early this morning, the board acknowledged their praise for the behavior of the fans during the championship game.
3 Temprano esta mañana, la junta reconoció su praise for the behavior of the fans during the championship game.
4 Temprano esta mañana, la junta reconoció sus elogios por el comportamiento de los aficionados durante el partido del campeonato.
1 Because we were not tired, we ordered cupcakes for our postre y hablamos un poco más.
2 Because we were not tired, we ordered cupcakes for our dessert and talked some more.
3 Debido a que no estabamos cansados, pedimos magdalenas para el dessert and talked some more.
4 Debido a que no estabamos cansados, pedimos magdalenas para el postre y hablamos un poco más.
1 Naively, Doug gave his stepbrother a bunch of dulce que lo hizo caer gravemente enfermo.
2 Naively, Doug gave his stepbrother a bunch of candy that made him get very sick.
3 Ingenuamente, Alfredo le dio a su hermanastro un montón de candy that made him get very sick.
4 Ingenuamente, Alfredo le dio a su hermanastro un montón de dulce que lo hizo caer gravemente enfermo.
1 Carol was very proud that her stuffing fit so well with the pavo y otros platillos este Acción de Gracias.
2 Carol was very proud that her stuffing fit so well with the turkey and other entrees this Thankgiving.
3 Camila estaba muy orgullosa de que su relleno quedara tan bien con el turkey and other entrees this Thankgiving.
4 Camila estaba muy orgullosa de que su relleno quedara tan bien con el pavo y otros platillos este Acción de Gracias.
1 The Bradleys like to buy onions and garlic from the granjero cada semana en el mercado local.
2 The Bradleys like to buy onions and garlic from the farmer each week at the local market.
3 A los García les gusta comprar cebollas y ajo del farmer each week at the local market.
4 A los García les gusta comprar cebollas y ajo del granjero cada semana en el mercado local.
1 Jack and Amanda handed out flyers for the venta muy temprano esta mañana.

2 Jack and Amanda handed out flyers for the sale very early this morning.
3 Alma y Alejo repartieron volantes para el sale very early this morning.
4 Alma y Alejo repartieron volantes para la venta muy temprano esta mañana.
1 Sadly, Cheryl forgot the basket for her hija y tuvo que encontrarse con ella con las manos vacías.
2 Sadly, Cheryl forgot the basket for her daughter and had to meet her empty handed.
3 Tristemente, Cheryl olvidó la canasta para su daughter and had to meet her empty handed.
4 Tristemente, Cheryl olvidó la canasta para su hija y tuvo que encontrarse con ella con las manos vacías.
1 The young parents bought a lot of pacifiers and enough ropa para durar hasta el tercer cumpleaños de su bebé.
2 The young parents bought a lot of pacifiers and enough clothes to last until their baby's third birthday.
3 Los jóvenes padres compraron un mónton de chupetes y bastante clothes to last until their baby's third birthday.
4 Los jóvenes padres compraron un mónton de chupetes y bastante ropa para durar hasta el tercer cumpleaños de su bebé.
1 Thomas, look at the ditch next to the columpios en el extremo este del campo de juego.
2 Thomas, look at the ditch next to the swings on the east end of the playground.
3 Tomás, mira la zanja al lado de los swings on the east end of the playground.
4 Tomás, mira la zanja al lado de los columpios en el extremo este del campo de juego.
1 Corey didn't realize he left his cooler on the muelle hasta que fue demasiado tarde.
2 Corey didn't realize he left his cooler on the pier until it was too late.
3 César no se dio cuenta de que dejó su hielera en el pier until it was too late.
4 César no se dio cuenta de que dejó su hielera en el muelle hasta que fue demasiado tarde.
1 Valerie left her wet canvas next to the caballete mientras sus niños pequeños corrían alrededor.
2 Valerie left her wet canvas next to the easel while her young kids were running around.
3 Valentina dejó su lienzo mojado al lado del easel while her young kids were running around.
4 Valentina dejó su lienzo mojado al lado del caballete mientras sus niños pequeños corrían alrededor.
1 Greg put some pencils on his escritorio en cuanto llegó a clase.
2 Greg put some pencils on his desk as soon as he got to class.
3 Gabriel puso algunos lápices en su desk as soon as he got to class.
4 Gabriel puso algunos lápices en su escritorio en cuanto llegó a clase.
1 He was angry because the plug for his plancha no estaba funcionando correctamente.
2 He was angry because the plug for his iron was not working properly.
3 Él estaba enojado porque el enchufe de su iron was not working properly.
4 Él estaba enojado porque el enchufe de su plancha no estaba funcionando correctamente.
1 She thoroughly enjoyed the snow and the paisaje de la cordillera.
2 She thoroughly enjoyed the snow and the landscape of the mountain range.
3 Ella disfrutó plenamente de la nieve y del landscape of the mountain range.
4 Ella disfrutó plenamente de la nieve y del paisaje de la cordillera.
1 The men always choose to drink water with the guiso en lugar de vino.
2 The men always choose to drink water with the stew rather than wine.
3 El hombre siempre elige beber agua con el stew rather than wine.
4 El hombre siempre elige beber agua con el guiso en lugar de vino.
1 The coach emphasized that fearlessness, ruthlessness, and fuerza eran las claves para ganar.
2 The coach emphasized that fearlessness, ruthlessness, and strength were the keys to winning.
3 El entrenador subrayó que la valentía, la misericodia y el strength were the keys to winning.
4 El entrenador subrayó que la valentía, la misericodia y la fuerza eran las claves para ganar.
1 Tiffany wanted for herself the jewels of the kings and reinas de toda Europa.
2 Tiffany wanted for herself the jewels of the kings and queens of all of Europe.
3 Teresa quería para ella las alhajas de los reyes y queens of all of Europe.
4 Teresa quería para ella las alhajas de los reyes y reinas de toda Europa.
1 He had been a locksmith in the condado durante los últimos cinco años.
2 He had been a locksmith in the county for the last five years.
3 Él había sido un cerrajero en el county for the last five years.
4 Él había sido un cerrajero en el condado durante los últimos cinco años.
1 Karina learned about moles, bones, and dientes en su clase de biología.
2 Karina learned about moles, bones, and teeth in her biology class.
3 Carmen aprendió sobre los lunares, los huesos y los teeth in her biology class.
4 Carmen aprendió sobre los lunares, los huesos y los dientes en su clase de biología.
1 For ten years, the old lizard lived in my cobertizo, comiendo ratones y espantando a otras criaturas del pantano.
2 For ten years, the old lizard lived in my shed, eating mice and scaring away the other swamp creatures.
3 Por diez años, el lagarto viejo vivió en mi shed, eating mice and scaring away the other swamp creatures.
4 Por diez años, el lagarto viejo vivió en mi cobertizo, comiendo ratones y espantando a otras criaturas del pantano.
1 She was taken aback by the ugliness of all the grabados de la exposición de arte.
2 She was taken aback by the ugliness of all the engravings in the art exhibit.
3 Ella se sorprendió de la fealdad de todos los engravings in the art exhibit.
4 Ella se sorprendió de la fealdad de todos los grabados de la exposición de arte.
1 Every year, the shopkeeper makes his own juguetes para los niños pequeños.
2 Every year, the shopkeeper makes his own toys for the young children.
3 Cada año, el tendero hace sus propios toys for the young children.

4 Cada año, el tendero hace sus propios juguetes para los niños pequeños.
1 One of the clowns broke through the muro mientras cantaba y bailaba.
2 One of the clowns broke through the wall while singing and dancing.
3 Uno de los payasos rompió el wall while singing and dancing.
4 Uno de los payasos rompió el muro mientras cantaba y bailaba.
1 The teachers take the kids to the libraries and the piscinas para darles a concocer la cultura local.
2 The teachers take the kids to the libraries and the pools to acquaint them with the local culture.
3 Los maestros llevan a los niños a las bibliotecas y los pools to acquaint them with the local culture.
4 Los maestros llevan a los niños a las bibliotecas y las piscinas para darles a concocer la cultura local.
1 Very little remained of the path and all the setos después de las Fuertes lluvias.
2 Very little remained of the path and all the hedges after the heavy rain.
3 Muy poco quedaba del sendero y todos los hedges after the heavy rain.
4 Muy poco quedaba del sendero y todos los setos después de las fuertes lluvias.
1 Olivia tried to find her lost earring in the pasillo de aquel hotel tan grande.
2 Olivia tried to find her lost earring in the hallway of the very large hotel.
3 Olivia trató de encontrar su arete perdido en el hallway of the very large hotel.
4 Olivia trató de encontrar su arete perdido en el pasillo de aquel hotel tan grande.
1 They raced from the fence to the gradas diez veces antes de decidir quién era más rápido.
2 They raced from the fence to the bleachers ten times before deciding who was faster.
3 Ellos corrieron de la cerca a los bleachers ten times before deciding who was faster.
4 Ellos corrieron de la cerca a las gradas diez veces antes de decidir quién era más rápido.
1 She looked at the screen next to the pizarra y alzó la mano para contestar la pregunta.
2 She looked at the screen next to the chalkboard and raised her hand to answer the question.
3 Ella miró la pantalla junto al chalkboard and raised her hand to answer the question.
4 Ella miró la pantalla junto a la pizarra y alzó la mano para contestar la pregunta.
1 This morning, Joel was craving eggs with some tocino o salchichas al lado.
2 This morning, Joel was craving eggs with some bacon or sausage on the side.
3 Esta mañana, a Joel se le antojaban huevos con un poco de bacon or sausage on the side.
4 Esta mañana, a Joel se le antojaban huevos con un poco de tocino o salchichas al lado.
1 He won't eat anything but mushrooms with those costillas y se niega a pedir algo diferente.
2 He won't eat anything but mushrooms with those ribs and refuses to order something different.
3 Él no quiere comer nada sino champiñones con esos ribs and refuses to order something different.
4 Él no quiere comer nada sino champiñones con esas costillas y se niega a pedir algo diferente.
1 Heather only dares to make pork on the parrilla cuando su marido está alrededor para venir al rescate.
2 Heather only dares to make pork on the grill when her husband is around for damage control.
3 Guadalupe sólo se atreve a hacer cerdo en el grill when her husband is around for damage control.
4 Guadalupe sólo se atreve a hacer cerdo en la parrilla cuando su marido está alrededor para venir al rescate.
1 They were not expecting the lightning or the granizada y tuvieron que correr rápidamente por seguridad.
2 They were not expecting the lightning or the hailstorm and had to quickly run to safety.
3 Ellos no esperaban los relámpagos o el hailstorm and had to quickly run to safety.
4 Ellos no esperaban los relámpagos o la granizada y tuvieron que corer rápidamente por seguridad.
1 By learning from wars and performance in siglos pasados, hemos mejorado nuestras estrategias militares de manera exponencial.
2 By learning from wars and performance in centuries past, we have improved our military strategies exponentially.
3 Al aprender de las guerras y del desempeño en centuries past, we have improved our military strategies exponentially.
4 Al aprender de las guerras y del desempeño en siglos pasados, hemos mejorado nuestras estrategias militares de manera exponencial.
1 In the fall, Michael harvests wheat and other siembras para vender en el mercado.
2 In the fall, Michael harvests wheat and other crops to sell in the market.
3 En el otoño, Miguel cosecha trigo y otros crops to sell in the market.
4 En el otoño, Miguel cosecha trigo y otras siembras para vender en el mercado.
1 After the noise complaint, the landlord spoke to the inquilino en privado y le dio una severa advertencia.
2 After the noise complaint, the landlord spoke to the tenant privately and gave him a severe warning.
3 Después de la queja por ruidos, el dueño habló con el tenant privately and gave him a severe warning.
4 Después de la queja por ruidos, el dueño habló con el inquilino en privado y le dio una severa advertencia.
1 He likes having his livestock next to the huerta porque facilita mantener un ojo en todo.
2 He likes having his livestock next to the orchard because it makes it easier to keep an eye on everything.
3 A él le gusta tener su granado al lado del orchard because it makes it easier to keep an eye on everything.
4 A él le gusta tener su granado al lado de la huerta porque facilita mantener un ojo en todo.
1 She always stores the wheelbarrow under a estante en su granero enorme.
2 She always stores the wheelbarrow under a shelf in her enormous barn.
3 Ella siempre pone la carretilla abajo de un shelf in her enormous barn.
4 Ella siempre pone la carretilla abajo de un estante en su granero enorme.
1 Sammy was displeased that the loudspeaker next to the buzones aún estaba roto a pesar de muchas llamadas al encargado.
2 Sammy was displeased that the loudspeaker next to the mailboxes was still broken despite many calls to the superintendent.
3 Salvador estaba molesto porque el altavoz al lado de los mailboxes was still broken despite many calls to the superintendent.
4 Salvador estaba molesto porque el altavoz al lado de los buzones aún estaba roto a pesar de muchas llamadas al encargado.

1 The Greeks felt a great surge of achievement and orgullo después de que derrotaran a los persas.
2 The Greeks felt a great surge of achievement and pride after they defeated the Persians.
3 Los griegos sintieron una gran oleada de logro y pride after they defeated the Persians.
4 Los griegos sintieron una gran oleada de logro y orgullo después de que derrotaran a los persas.
1 She bought these paintbrushes for the retrato que se volvió muy famoso.
2 She bought these paintbrushes for the portrait that became very famous.
3 Ella compró estos pinceles para el portrait that became very famous.
4 Ella compró estos pinceles para el retrato que se volvió muy famoso.
1 The left lane of the highway is closed due to inundaciones por el resto de la semana.
2 The left lane of the highway is closed due to flooding for the rest of the week.
3 El carril izquierdo de la autopista está cerrado debido al flooding for the rest of the week.
4 El carril izquierdo de la autopista está cerrado debido a las inundaciones por el resto de la semana.
1 Even though he was in pain, the handyman climbed to the techo para trabajar desde un ángulo mejor.
2 Even though he was in pain, the handyman climbed to the roof to work from a better angle.
3 A pesar de que estaba dolorido, el manitas se subió al roof to work from a better angle.
4 A pesar de que estaba dolorido, el manitas se subió al techo para trabajar desde un ángulo mejor.
1 Yesterday, Jennifer purchased soaps for the ducha del baño de arriba.
2 Yesterday, Jennifer purchased soaps for the shower in the upstairs bathroom.
3 Ayer, Jenifer compró jabones para el shower in the upstairs bathroom.
4 Ayer, Jenifer compró jabones para la ducha del baño de arriba.
1 They carefully lifted the bookcase onto the montacargas y se alejaron lentamente.
2 They carefully lifted the bookcase onto the forklift and slowly drove away.
3 Ellos levantaron cuidadosamente la estantería en el forklift and slowly drove away.
4 Ellos levantaron cuidadosamente la estantería en el montacargas y se alejaron lentamente.
1 The king rode an ostrich across the puente hacia las tierras adyacentes.
2 The king rode an ostrich across the bridge into the adjacent lands.
3 El rey montó un avestruz a través del bridge into the adjacent lands.
4 El rey montó un avestruz a través del puente hacia las tierras adyacentes.
1 The loose sheets fell out of her briefcase into the charco mientras caminaba por la calle.
2 The loose sheets fell out of her briefcase into the puddle while walking down the street.
3 Las hojas sueltas se cayeron de su maletín en el puddle while walking down the street.
4 Las hojas sueltas se cayeron de su maletín en el charco mientras caminaba por la calle.
1 This year, his niece wants a helmet and patines para su cumpleaños.
2 This year, his niece wants a helmet and skates for her birthday.
3 Este año, su sobrina quiere un casco y skates for her birthday.
4 Este año, su sobrina quiere un casco y patines para su cumpleaños.
1 He turned on the heater in the lavadero y continuó con su proyecto.
2 He turned on the heater in the washroom and continued his project.
3 Él prendió el calentador en el washroom and continued his project.
4 Él prendió el calentador en el lavadero y continuó con su proyecto.
1 To make matters worse, he found bedbugs in addition to the hormigas que ya estaban causando problemas a los propietarios.
2 To make matters worse, he found bedbugs in addition to the ants that were already causing problems for the homeowners.
3 Para empeorar las cosas, él encontró chinches además de los ants that were already causing problems for the homeowners.
4 Para empeorar las cosas, él encontró chinches además de las hormigas que ya estaban causando problemas a los propietarios.
1 Phil and Jamie played with their puzzles on the colcha hasta que fue hora de ver la televisión.
2 Phil and Jamie played with their puzzles on the quilt until it was time to watch television.
3 Adriana y Liliana jugaron con su rompecabezas en el quilt until it was time to watch television.
4 Adriana y Liliana jugaron con su rompecabezas en la colcha hasta que fue hora de ver la televisión.
1 She didn't want to leave the snacks with the gemelos por miedo a que hubiera un gran lío cuando regresara.
2 She didn't want to leave the snacks with the twins for fear that there would be a huge mess when she returned.
3 Ella no quería dejar las meriendas con los twins for fear that there would be a huge mess when she returned.
4 Ella no quería dejar las meriendas con los gemelos por miedo a que hubiera un gran lío cuando regresara.
1 Anne was overwhelmed by the loan on her hipoteca pero no había nada que pudiera hacer al respecto.
2 Anne was overwhelmed by the loan on her mortgage but there was nothing she could do about it.
3 Ana estaba abrumada por el préstamo de su mortgage but there was nothing she could do about it.
4 Ana estaba abrumada por el préstamo de su hipoteca pero no había nada que pudiera hacer al respecto.
1 He walked outside to find drenched furniture near the rociadores y su ánimo al instante se volvió agrio.
2 He walked outside to find drenched furniture near the sprinklers and his mood instantly turned sour.
3 Él salió y encontró los muebles empapados cerca de los sprinklers and his mood instantly turned sour.
4 Él salió y encontró los muebles empapados cerca de los rociadores y su ánimo al instante se volvió agrio.
1 With the help of a crane, he moved boxes full of herramientas y materiales de construcción.
2 With the help of a crane, he moved boxes full of tools and building supplies.
3 Con la ayuda de una grúa, él trasladó cajas llenas de tools and building supplies.
4 Con la ayuda de una grúa, él trasladó cajas llenas de herramientas y materiales de construcción.
1 She bought more hairspray as well as afeitadoras ya que estaba a punto de quedarse sin los dos.
2 She bought more hairspray as well as razors since she was close to running out of both.

3	Ella compró más laca además de razors since she was close to running out of both.
4	Ella compró más laca además de afeitadoras ya que estaba a punto de quedarse sin los dos.
1	Whether it's the dishwasher or the secadora, Consuelo odia todo lo que tiene que ver con la limpieza.
2	Whether it's the dishwasher or the dryer, Kathy hates everything to do with cleaning.
3	Ya sea el lavaplatos o el dryer, Kathy hates everything to do with cleaning.
4	Ya sea el lavaplatos o la secadora, Consuelo odia todo lo que tiene que ver con la limpieza.
1	She fixed the ripped sleeve of the sudadera porque no pudo soportar desprenderse de ella.
2	She fixed the ripped sleeve of the sweatshirt because she couldn't bear to part with it.
3	Ella arregló la manga rasgada del sweatshirt because she couldn't bear to part with it.
4	Ella arregló la manga rasgada de la sudadera porque no pudo soportar desprenderse de ella.
1	Gabriella ended up with a bruise on her espalda después de una noche escandalosa.
2	Gabriella ended up with a bruise on her back after a rowdy night out.
3	Gabriella acabó con un moretón en su back after a rowdy night out.
4	Gabriella acabó con un moretón en su espalda después de una noche escandalosa.
1	They rushed to the courthouse after the tiroteo que causó estragos en muchas personas.
2	They rushed to the courthouse after the shooting that caused havoc for many people.
3	Ellos corrieron al juzgado después del shooting that caused havoc for many people.
4	Ellos corrieron al juzgado después del tiroteo que causó estragos en muchas personas.
1	He was given an award for his deportividad durante el torneo.
2	He was given an award for his sportsmanship during the tournament.
3	A él le dieron un premio por su sportsmanship during the tournament.
4	A él le dieron un premio por su deportividad durante el torneo.

References

Alameda, J.R., Cuetos, F., 1995. Diccionario de Frecuencias de las Unidades Linguisticas del Castellano. Servicio de Publicaciones Universidad de Oviedo, Oviedo.

Alvarez, R.P., Holcomb, P.J., Grainger, J., 2003. Accessing word meaning in two languages: an event-related brain potential study of beginning bilinguals. Brain Lang. 87 (2), 290–304.

Baayen, R.H., Piepenbrock, R., Van Rijn, H., 1993. The Celex Lexical Database (CD-ROM). University of Pennsylvania Linguistic Data Consortium, Philadelphia.

Bakker, I., Takashima, A., Van Hell, J.G., Janzen, G., McQueen, J.M., 2015. Changes in theta and beta oscillations as signatures of novel word consolidation. J. Cogn. Neurosci. 27 (7), 1286–1297.

Bastiaansen, M., Hagoort, P., 2006. Oscillatory neuronal dynamics during language comprehension. Prog. Brain Res. 159, 179–196.

Bastiaansen, M., Hagoort, P., 2015. Frequency-based segregation of syntactic and semantic unification during online sentence level language comprehension. J. Cogn. Neurosci. 27 (11), 2095–2107.

Bobb, S.C., Wodniecka, Z., 2013. Language switching in picture naming: what asymmetric switch costs (do not) tell us about inhibition in bilingual speech planning. J. Cogn. Psychol. 25 (5), 568–585.

Bultena, S., Dijkstra, T., Van Hell, J.G., 2015a. Language switch costs in comprehension depend on language dominance: evidence from self-paced reading. Biling.: Lang. Cogn. 18, 453–469.

Bultena, S., Dijkstra, T., Van Hell, J.G., 2015b. Switch cost modulations in bilingual sentence processing: evidence from shadowing. Lang. Cogn. NeuroSci. 30, 586–605.

Chauncey, K., Grainger, J., Holcomb, P.J., 2008. Code-switching effects in bilingual word recognition: a masked priming study with event-related potentials. Brain Lang. 105 (3), 161–174.

Clyne, M.G., 1967. Transference and Triggering: Observations on the Language Assimilation of Postwar German-Speaking Migrants in Australia. Martinus Nijhoff, Den Haag.

Costa, A., Santesteban, M., 2004. Lexical access in bilingual speech production: evidence from language switching in highly proficient bilinguals and L2 learners. J. Mem. Lang. 50 (4), 491–511.

Costa, A., Caramazza, A., Sebastián-Gallés, N., 2000. The cognate facilitation effect: implications for models of lexical access. J. Exp. Psychol.: Lean. Mem. Cogn. 26 (5), 1283–1296.

De Groot, A.M.B., Dannenburg, L., Van Hell, J.G., 1994. Forward and backward word translation by bilinguals. J. Mem. Lang. 33, 600–629.

Declerck, M., Philipp, A.M., 2015. A review of control processes and their locus in language switching. Psychon. Bull. Rev. 22 (6), 1630–1645.

Declerck, M., Koch, I., Philipp, A.M., 2012. Digits vs. pictures: the influence of stimulus type on language switching. Biling.: Lang. Cogn. 15 (04), 896–904.

Dijkstra, T., 2005. Bilingual visual word recognition and lexical access. In: Kroll, J.F., De Groot, A.M.B. (Eds.), Handbook of Bilingualism: Psycholinguistic Approaches. Oxford University Press, New York, NY.

Dijkstra, T., Van Heuven, W.J.B., 2002. The architecture of the bilingual word recognition system: from identification to decision. Biling.: Lang. Cogn. 5 (3), 175–197.

Dijkstra, T., Van Hell, J.G., Brenders, P., 2015. Sentence context effects in bilingual word recognition: cognate status, sentence language, and semantic constraint. Biling.: Lang. Cogn. 18, 597–613.

Donchin, E., 1981. Surprise!... surprise? Psychophysiology 18 (5), 493–513.

Dussias, P.E., Dietrich, A., Villegas, A., 2015. Cross-language interactions during bilingual sentence processing. In: Schwieter, J. (Ed.), The Cambridge Handbook of Bilingual Language Processing. Cambridge University Press, Cambridge, England.

Emmorey, K., Luk, G., Pyers, J.E., Bialystok, E., 2008. The source of enhanced cognitive control in bilinguals: evidence from bimodal bilinguals. Psychol. Sci. 19, 1201–1206.

Engel, A.K., Fries, P., 2010. Beta-band oscillations—signalling the status quo? Curr. Opin. Neurobiol. 20 (2), 156–165.

Fairchild, S., Van Hell, J.G., 2017. Determiner-noun code-switching in Spanish heritage speakers. Biling.: Lang. Cogn. 20, 150–161.

Filippi, R., Karaminis, T., Thomas, M.S.C., 2014. Language switching in bilingual production: empirical data and computational modelling. Biling.: Lang. Cogn. 17 (02), 294–315.

Folstein, J.R., Van Petten, C., 2008. Influence of cognitive control and mismatch on the N2 component of the ERP: a review. Psychophysiology 45, 152–170.

Forster, K.I., Guerrera, C., Elliot, L., 2009. The maze task: measuring forced incremental sentence processing time. Behav. Res. Methods 41, 163–171.

Grainger, J., Midgley, K.J., Holcomb, P.J., 2010. Re-thinking the bilingual interactive-activation model from a developmental perspective (BIA-d). Lang. Acquis. Across Linguist. Cogn. Syst. 52, 267–284.

Green, D.W., 1998. Mental control of the bilingual lexico-semantic system. Biling.: Lang. Cogn. 1, 67–81.

Green, D.W., 2011. Language control in different contexts: the behavioral ecology of bilingual speakers. Front. Psychol., 1–4.

Green, D.W., Wei, L., 2014. A control process model of code-switching. Lang. Cogn. Neurosci. 29 (4), 499–511.

Grosjean, F., 2001. The bilingual's language modes. In: Nicol, J. (Ed.), One Mind, Two Languages: Bilingual Language Processing. Blackwell, Oxford.

Gullifer, J.W., Kroll, J.F., Dussias, P.E., 2013. When language switching has no apparent cost: lexical access in sentence context. Front. Psychol. 4 (278), 1–13.

Gunter, T.C., Stowe, L.A., Mulder, G., 1997. When syntax meets semantics. Psychophysiology 34, 660–676.

Guzzardo Tamargo, R., Valdés Kroff, J.R., Dussias, P.E., 2016. Examining the relationship between comprehension and production processes in code-switched language. J. Mem. Lang. 89, 138–161.

Heredia, R.R., Altarriba, J., 2001. Bilingual language mixing: why do bilinguals code-switch? Curr. Dir. Psychol. Sci. 10 (5), 164–168.

Herring, J.R., Deuchar, M., Couto, M.C.P., Quintanilla, M.M., 2010. "I saw the madre": evaluating predictions about codeswitched determiner-noun sequences using Spanish–English and Welsh–English data. Int. J. Biling. Educ. Biling. 13 (5), 553–573.

Ibáñez, A.J., Macizo, P., Bajo, M.T., 2010. Language access and language selection in professional translators. Acta Psychol. 135 (2), 257–266.

Jackson, G.M., Swainson, R., Cunnington, R., Jackson, S.R., 2001. ERP correlates of executive control during repeated language switching. Biling.: Lang. Cogn. 4 (2), 169–178.

Jake, J.L., Myers-Scotton, C., Gross, S., 2002. Making a minimalist approach to codeswitching work: adding the matrix language. Biling.: Lang. Cogn. 5, 69–91.

Just, M.A., Carpenter, P.A., Woolley, J.D., 1982. Paradigms and processes in reading comprehension. J. Exp. Psychol.: Gen. 111 (2), 228–238.

Kaplan, E., Goodlass, H., Weintraub, S., 2001. Boston Naming Test (Second.). Lippincott Williams & Wilkins Publishers, Philadelphia, PA.

King, J.W., Kutas, M., 1995. Who did what and when? Using word- and clause-level ERPs to monitor working memory usage in reading. J. Cogn. Neurosci. 7 (3), 376–395.

Kolk, H., Chwilla, D., 2007. Late positivities in unusual situations. Brain Lang. 100 (3), 257–261.
Kutas, M., Hillyard, S.A., 1980. Reading senseless sentences: brain potentials reflect semantic incongruity. Science 207 (4427), 203–205.
Lewis, A.G., Wang, L., Bastiaansen, M., 2015. Fast oscillatory dynamics during language comprehension: unification versus maintenance and prediction? Brain Lang. 148, 51–63.
Liceras, J.M., Spradlin, K.T., Fuertes, R.F.A.N., 2005. Bilingual early functional-lexical mixing and the activation of formal features. Int. J. Biling. 9 (2), 227–252.
Liu, H., Liang, L., Zhang, L., Lu, Y., Chen, B., 2017. Modulatory role of inhibition during language switching: evidence from evoked and induced oscillatory activity. Int. J. Biling. 21 (1), 57–80.
Lopez-Calderon, J., Luck, S.J., 2014. ERPLAB: an open-source toolbox for the analysis of event-related potentials. Front. Hum. Neurosci. 8 (213), 1–14.
Luck, S.J., 2014. An Introduction to the Event-related Potential Technique. MIT Press, Cambridge, MA.
Macizo, P., Bajo, T., Paolieri, D., 2012. Language switching and language competition. Second Lang. Res. 28 (2), 131–149.
Marian, V., Spivey, M., 2003. Competing activation in bilingual language processing: within- and between-language competition. Biling.: Lang. Cogn. 6 (2), 97–115.
Marian, V., Shook, A., 2012, September. The cognitive benefits of being bilingual. In Cerebrum: the Dana Forum on Brain Science. Vol. 2012. Dana Foundation.
Maris, E., Oostenveld, R., 2007. Nonparametric statistical testing of EEG- and MEG-data. J. Neurosci. Methods 164 (1), 177–190.
Meuter, R.F.I., Allport, A., 1999. Bilingual language switching in naming: asymmetrical costs of language selection. J. Mem. Lang. 40, 25–40.
Milroy, L., Muysken, P., 1995. One Speaker, Two Languages. Cross-Disciplinary Perspectives on Code-Switching. Cambridge University Press, Cambridge.
Moreno, E.M., Federmeier, K.D., Kutas, M., 2002. Switching languages, switching palabras (words): an electrophysiological study of code switching. Brain Lang. 80, 188–207.
Moreno, E.M., Rodriguez-Fornells, A., Laine, M., 2008. Event-related potentials (ERPs) in the study of bilingual language processing. J. Neurolinguist. 21 (6), 477–508.
Muysken, P., 2000. Bilingual Speech: A Typology of Code Mixing. Cambridge University Press, Cambridge.
Myers-Scotton, C., Jake, J.L., 2013. Nonfinite verbs and negotiating bilingualism in codeswitching: implications for a language production model. Biling.: Lang. Cogn. 17 (03), 511–525.
Ng, S., Gonzalez, C., Wicha, N.Y.Y., 2014. The fox and the cabra: an ERP analysis of reading code switched nouns and verbs in bilingual short stories. Brain Res. 1557, 127–140.
Oostenveld, R., Fries, P., Maris, E., Schoffelen, J.-M., 2010. FieldTrip: open source software for advanced analysis of MEG, EEG, and invasive electrophysiological data. Comput. Intell. Neurosci. 2010 (1), 1–9.
Pfaff, C.W., 1979. Constraints on language mixing: intrasentential code-switching and borrowing in Spanish/English. Language 55, 291–318.
Philipp, A.M., Gade, M., Koch, I., 2007. Inhibitory processes in language switching: evidence from switching language-defined response sets. Eur. J. Cogn. Psychol. 19 (3), 395–416.
Polich, J., 2007. Updating P300: an integrative theory of P3a and P3b. Clin. Neurophysiol. 118 (10), 2128–2148.
Poplack, S., 1980. Sometimes I'll start a sentence in Spanish Y TERMINO EN ESPANOL: toward a typology of code-switching. Linguistics 18, 581–618.
Proverbio, A.M., Leoni, G., Zani, A., 2004. Language switching mechanisms in simultaneous interpreters: an ERP study. Neuropsychologia 42 (12), 1636–1656.
Reynolds, M.G., Schlöffel, S., Peressotti, F., 2015. Asymmetric switch costs in numeral naming and number word reading: implications for models of bilingual language production. Front. Psychol. 6, 2011.
Sassenhagen, J., Schlesewsky, M., Bornkessel-Schlesewsky, I., 2014. The P600-as-P3 hypothesis revisited: single-trial analyses reveal that the late EEG positivity following linguistically deviant material is reaction time aligned. Brain Lang. 137, 29–39.
Slevc, L.R., Davey, N.S., Linck, J.A., 2016. A new look at "the hard problem" of bilingual lexical access: evidence for language-switch costs with univalent stimuli. J. Cogn. Psychol. 28 (4), 385–395.
Tanner, D., Grey, S.E., Van Hell, J.G., 2017. Dissociating retrieval interference and reanalysis in the P600 during sentence comprehension. Psychophysiology 54 (2), 248–259.
Tarlowski, A., Wodniecka, Z., Marzecová, A., 2013. Language switching in the production of phrases. J. Psycholinguist. Res. 42 (2), 103–118.
Turner, M.L., Engle, R.W., 1989. Is working memory capacity task dependent? J. Mem. Lang. 28 (2), 127–154.
Valdés Kroff, J.R., Dussias, P.E., Gerfen, C., Perrotti, L., Bajo, M.T., 2016. Experience with code-switching modulates the use of grammatical gender during sentence processing. Linguist. Approach. Biling.. http://dx.doi.org/10.1074/lab.15010.val, Advance Online Publication.
Van Assche, E., Duyck, W., Hartsuiker, R.J., Diependaele, K., 2009. Does bilingualism change native-language reading? Psychol. Sci. 20 (8), 923–927.
Van Der Meij, M., Cuetos, F., Carreiras, M., Barber, H.A., 2011. Electrophysiological correlates of language switching in second language learners. Psychophysiology 48 (1), 44–54.
Van Hell, J.G., Dijkstra, T., 2002. Foreign language knowledge can influence native language performance in exclusively native contexts. Psychon. Bull. Rev. 9 (4), 780–789.
Van Hell, J.G., Tanner, D., 2012. Second language proficiency and cross-language lexical activation. Lang. Learn. 62, 148–171.
Van Hell, J.G., Litcofsky, K.A., Ting, C.Y., 2015. Sentential code-switching: cognitive and neural approaches. In: Schwieter, J.W. (Ed.), The Cambridge Handbook of Bilingual Processing. Cambridge University Press, Cambridge, UK, 459–482.
Van Petten, C., Luka, B.J., 2012. Prediction during language comprehension: benefits, costs, and ERP components. Int. J. Psychophysiol. 83 (2), 176–190.
Verhoef, K., Roelofs, A., Chwilla, D.J., 2009. Role of inhibition in language switching: evidence from event-related brain potentials in overt picture naming. Cognition 110, 84–99.
Vitevitch, M.S., Rodríguez, E., 2004. Neighborhood density effects in spoken word recognition in Spanish. J. Multiling. Commun. Dis. 3 (1), 64–73.
Wang, X., 2015. Language control in bilingual language comprehension: evidence from the maze task. Front. Psychol. 6 (137), 242.
Wei, L., Milroy, L., 1995. Conversational code-switching in a Chinese community in Britain: a sequential analysis. J. Pragmat. 23, 281–299.
Weiss, S., Mueller, H.M., 2012. "Too many betas do not spoil the broth": the role of beta brain oscillations in language processing. Front. Psychol. 3 (201), 1–15.
Weiss, S., Mueller, H.M., Schack, B., King, J.W., Kutas, M., Rappelsberger, P., 2005. Increased neuronal communication accompanying sentence comprehension. Int. J. Psychophysiol. 57 (2), 129–141.
Woolford, E., 1983. Bilingual code-switching and syntactic theory. Linguist. Inq. 14 (3), 520–536.