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Bilingual experience shapes language processing: Evidence from codeswitching

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ABSTRACT

We report three experiments on two groups of Spanish–English bilinguals who differed in codeswitching experience (codeswitchers and non-codeswitchers) to examine how different production choices predict comprehension difficulty. Experiment 1 examined the processing of gender congruent and gender incongruent determiner-noun switches in sentential contexts using event-related potentials. While codeswitchers demonstrated N400 sensitivity to congruency manipulations, non-codeswitchers showed a modulation of early frontal EEG activity to switching, regardless of switch type. Experiment 2 validated the translation-equivalent target words compared in Experiment 1. In Experiment 3, the bilinguals who participated in Experiment 1 completed a task that elicited naturally-produced codeswitched speech. Codeswitchers switched more often than non-codeswitchers, and their switches robustly reflected the conditions that were more easily processed in Experiment 1. Together, the results indicate the comprehension system becomes optimally attuned to variation in the input, and demonstrate that switching costs depend on the type of codeswitch and bilinguals' language experience.

Introduction

A unique feature of bilingual communication is that many bilinguals sometimes alternate between languages when speaking to other bilinguals. While not all bilinguals engage in *codeswitching*, those who do are able to do so without any apparent disruptions to production or comprehension (Myers-Scotton & Jake, 2015; Poplack, 1980). The following conversational exchange between two Spanish-English bilingual speakers illustrates such linguistic behavior.[1]

(1) I was like, si me hacen una pregunta de how would I say this. I wouldn't be able to say it si me están haciendo consciously say it.
'I was like, if they ask me a question on how I would say this. I wouldn't be able to say it if they are making me consciously say it.'

From a psycholinguistic perspective, codeswitching bears the hallmark of cross-language activation and represents a research tool to examine how bilinguals systematically (dis)engage two languages (Green & Abutalebi, 2013; Kroll, Dussias, Bice, & Perrotti, 2015; Kroll, Dussias, Bogulski, & Valdés Kroff, 2012). It has been well established in the psycholinguistic literature that a bilingual's two languages are active even when speakers intend to produce or comprehend one language alone (Kroll, Bobb, & Hoshino, 2014; Kroll & De Groot, 2005). Despite this interactivity, errors in which bilinguals select the unintended language are strikingly rare in unilingual contexts (Bobb & Wodniecka, 2013; Kroll et al., 2012; Poulisse & Bongaerts, 1994). At the same time, we know that bilinguals who habitually engage in codeswitching do not haphazardly switch between languages, even in the face of heightened co-activation (Deuchar, 2005; Lipski, 1978; Pfaff, 1979; Poplack, 1980). This leaves open the question of how bilinguals successfully integrate both languages in the production and comprehension of codeswitched discourse. Although research on codeswitching is increasingly growing, the processes that mediate the production and comprehension of codeswitching are not well understood (Green & Wei, 2014). One possibility explored in this paper is that production and comprehension processes may be differentially tuned by language experience. Crucially, codeswitching provides a unique opportunity to examine how bilinguals regulate the use of

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[1] The example is reproduced verbatim from the Codeswitching Map Task corpus (Beatty-Martínez, Navarro-Torres, Parafita Couto, & Dussias, 2017). Spanish is underlined; the non-codeswitched English translation is given below the original transcript in italics.

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their languages throughout their daily lives. Because codeswitching emerges in some bilingual communities but not in others, it is possible to examine more readily how the production and comprehension systems become optimally attuned to variation in the input, and how the comprehension system uses this information during language comprehension. The current study seeks to exploit this relationship by examining the extent to which individuals' production choices can predict comprehension difficulty in codeswitching and non-codeswitching bilingual populations.

The remainder of this paper is structured as follows. First, we describe documented production asymmetries in codeswitching corpora. Then, we review previous findings on the production and the comprehension of codeswitched language both in experimental and naturalistic settings. Next, we present the goals and design of the current study. We report the findings of two event-related potential (ERP) studies conducted to examine the processing of different types of codeswitches, and present the results of a codeswitching elicitation task to confirm the production asymmetries discussed below by assessing the codeswitching preferences among two bilingual groups. We end with a general discussion of the results.

Production asymmetries in the production of mixed noun phrases

In unilingual contexts, production preferences emerge as choices among structures. Subcategorization biases (Dussias & Cramer Scaltz, 2008; Garnsey, Pearlmutter, Myers, & Lotocky, 1997; Trueswell, Tanenhaus, & Kello, 1993) are an example of such preferences. For verbs with alternative complementation patterns (e.g., 'believe' vs. 'confirm'), it has been found that preferences for associating verbs with a particular argument structure can influence speech production (Gahl & Garnsey, 2004) and speech comprehension (Wilson & Garnsey, 2009). In a codeswitching context, production preferences emerge as choices between languages. Identification of distributional patterns is achieved by the quantification and extraction of structural alternations from naturalistic corpora (Poplack, 1980, 2015). Most relevant for purposes of the current study are switches within the noun phrase in Spanish-English codeswitching (henceforth mixed NPs; Clegg, 2006; Jake, Myers-Scotton, & Gross, 2002; Otheguy & Lapidus, 2003).

Previous studies examining the distributional patterns of mixed NPs have reported two robust asymmetries (Clegg, 2006; Jake et al., 2002; Pfaff, 1979; Poplack, 1980). The first concerns the direction of the switch: switches between the Spanish determiner and the English noun (e.g., 'el dog', "the$_{SPAN}$ dog$_{ENG}$") have been found to occur more frequently than switched in the opposite direction (e.g., 'the perro', "the$_{ENG}$ dog$_{SPAN}$"). The second asymmetry involves grammatical gender assignment: Spanish-English bilinguals in some codeswitching communities exhibit an overall preference for the masculine-marked determiners (e.g., el, "the$_{MASC}$") regardless of the English noun's Spanish translation equivalent (e.g., 'el$_{MASC}$ fork$_{MASC}$' and 'el$_{MASC}$ spoon$_{FEM}$'). In contrast, switches with the feminine-marked determiners (e.g., la, "the$_{FEM}$") occur less frequently and are restrictively used with feminine translation equivalents ('la$_{FEM}$ spoon$_{FEM}$' but not 'la$_{FEM}$ fork$_{MASC}$').

In Valdés Kroff's (2016) analysis of the Bangor Miami corpus (Deuchar, Davies, Herring, Parafita Couto, & Carter, 2014), quantification of the distribution of mixed NPs revealed 322 total instances, of which 5% were composed of an English determiner followed by a Spanish noun, and 95% of a Spanish determiner followed by an English noun. Further decomposition of this distribution revealed that 92% of Spanish-to-English codeswitches were preceded by a masculine determiner while only 3% were preceded by a feminine determiner. This production asymmetry differs from that in unilingual Spanish contexts, where masculine and feminine nouns are evenly distributed (Eddington, 2002; Otheguy & Lapidus, 2003). The fact that grammatical gender is absent in English suggests the use of a codeswitching strategy that results from the interaction between the two grammars.

A point worth emphasizing is that, while previously proposed linguistically-based constraints (e.g., Lipski, 1978; Pfaff, 1979; Poplack, 1980) have predicted mixed NPs as a feasible switch point because Spanish and English share the same surface order, these constraints do not predict asymmetric distributions in mixed NPs with respect to grammatical gender assignment of the determiner, nor do they predict asymmetries in the direction of the switch. The purpose of this paper is not to explain why these asymmetries might arise (although we touch upon this in the discussion section). Instead, it tests whether bilingual speakers are sensitive to this variation in ways that constrain the comprehension system.

Switch costs during the production of codeswitches

The language-switching task (e.g., Meuter & Allport, 1999) has been the benchmark method to investigate the processes underlying bilingual language production (Bobb & Wodniecka, 2013; Tarlowski, Wodniecka, & Marzecová, 2013). In this paradigm, bilinguals name items out of context (e.g., numeric digits or pictures) in one of their two languages as indicated by external cues (e.g., color font or frame). On non-switch trials, participants name the target item in the same language as the preceding trial. On switch trials, participants name the target item in the opposite language than on the preceding trial. Switching costs are determined by calculating latency differences between switch and non-switch trials. The canonical finding in this paradigm is a switch cost: switch trials elicit longer reaction times than non-switch trials (see Meuter (2009), for a review). Switch costs are typically asymmetric, such that participants take longer to name a target in their first language (L1) following a trial in their second language (e.g., Meuter & Allport, 1999).

Another finding is that linguistic proficiency in the second language (L2) can modulate the magnitude of this effect (e.g., Costa & Santesteban, 2004). Studies investigating the presence of switch costs in sentence level contexts have reported mixed findings. Bultena, Dijkstra, and van Hell (2014) found that switching to the L2 was more costly than switching to the L1, and Tarlowski et al. (2013) found asymmetrical switching costs that differed depending on the grammatical structure produced. Gullifer, Kroll, and Dussias (2013), on the other hand, found that bilinguals did not differ in naming times for target words embedded in mixed and blocked sentence contexts. Studies examining codeswitching in naturalistic contexts have asked whether there is a cost associated with spontaneously-produced codeswitches. In an analysis of the Bangor Miami Corpus (Deuchar et al., 2014), Fricke, Kroll, and Dussias (2016) found that even when highly proficient codeswitchers retain full control over when to switch languages, switching resulted in slowed speech rate and a modulation of cross-language phonological overlap; this suggests that language regulation has consequences for processes occurring during speech planning. Overall, these findings pose an interesting paradox: if bilingual speakers exhibit larger processing costs when switching languages, why do they customarily codeswitch?

Although this question has not been addressed in depth, recent work looking at codeswitching from a conceptual point of view capitalizes on the role of opportunistic planning in the production of codeswitches (Green & Abutalebi, 2013; Green & Wei, 2014, 2016). According to this account, codeswitching plays an important role in mitigating utterance planning difficulties in bilinguals. For example, if speakers intend to use a specific word in the language not currently in use, they may deliberately switch to more precisely express the intended message. Another scenario said to increase the likelihood of codeswitching includes instances where circumventing a lexical gap is more efficient than staying in the current language. Green and Wei (2014, 2016) hypothesize that in these cases, switched items may be retrieved more rapidly because they are temporarily more active and available than other competing alternatives. Under these circumstances, although the intention to switch languages can give rise to a processing cost, codeswitching may act as a strategy to avoid disrupted speech planning. If statistical regularities during codeswitching act as cues to language regulation, we can then ask whether bilinguals take advantage of these cues to anticipate upcoming codeswitches in comprehension. This is the goal of the present study.

Switch costs during the comprehension of codeswitches

Psycholinguistic evidence on the comprehension of codeswitches is primarily drawn from experiments on single noun insertions embedded in sentential contexts. In analogy to language switching studies, switched stimuli have been found to increase processing difficulty. This is shown behaviorally in the form of longer reading times (e.g., Altarriba, Kroll, Sholl, & Rayner, 1996), and in studies recording electrophysiological responses to the modulation of ERP components (e.g., the N400 effect; see Proverbio, Leoni, & Zani, 2004). However, some electrophysiological studies have found that single noun switches elicit a late positivity complex (LPC) both in meaningful sentences (Moreno, Federmeier, & Kutas, 2002) and in a discourse context (Ng, Gonzalez, & Wicha, 2014). This ERP component is typically sensitive to the processing of an improbable event (Kutas & Hillyard, 1984). For example, Moreno et al. (2002) carried out a study comparing expected English nouns (example 2a below) to within-language switches (i.e., synonyms; example 2b) and between-language switches (i.e., Spanish translations of the expected noun; example 2c) while English-Spanish bilinguals read for comprehension.

(2) a. He put a clean sheet on the bed. [non-switch condition]
b. He put a clean sheet on the mattress. [within-language switch condition]
c. He put a clean sheet on the <u>cama</u>. [between-language switch condition]

Moreno et al. (2002) observed that the processing of within- and between-language switches incurred different costs. Whereas within-language switches elicited an increased N400 response compared to expected English words, between-language switches showed an enhanced LPC. The LPC response to codeswitches was interpreted as an index of a surprising event, and not as a processing cost associated with lexical-semantic integration. This might suggest that a codeswitch, albeit unexpected, may not necessarily be more difficult to process than within-language switches involving synonyms.

While it has been reported that bilingual speakers do not provide explicit cues signaling a codeswitch and that, oftentimes, bilinguals cannot recall switch points accurately (Poplack, 1980), this does not mean that an upcoming codeswitch is necessarily unpredictable. If cues were nonexistent in the input, listeners would experience comprehension difficulties when processing a codeswitch. Counter to this prediction, studies have found that bilingual speakers use subtle implicit cues to process upcoming codeswitches (Balukas & Koops, 2015; Myslín & Levy, 2015; Piccinini & Arvaniti, 2015). Bilingual listeners have been observed to develop sensitivity to these cues such that they implicitly are able to use this information to predict whether a switch in language might occur. For example, through the analysis of spontaneous codeswitched speech, Fricke et al. (2016) found that the phonetic properties of bilingual speech were modulated in anticipation of a codeswitch. In a subsequent comprehension experiment using the visual world paradigm, they found that bilinguals were able to perceive and exploit the cues leading up to upcoming codeswitches.

For purposes of the current study, we examine the extent to which the distributional regularities involving mixed NPs described earlier act as cues heightening the probability of upcoming switches. Guzzardo Tamargo, Valdés Kroff, and Dussias (2016) examined bilinguals' sensitivity to production asymmetries in Spanish-English codeswitches at the auxiliary + participle phrase by comparing codeswitches involving progressive and perfect structures. Their quantification of these two structures in bilingual corpora revealed that codeswitches at the progressive site ('*<u>están</u> working*', "are$_{SPAN}$ working$_{ENG}$") were more frequent than those at the perfect site ('*<u>han</u> worked*', "have$_{SPAN}$ worked$_{ENG}$). The consequence of these distributional differences was subsequently tested in an eye-tracking study with bilingual codeswitchers. Participants' comprehension costs were found to mirror the production patterns in codeswitching corpora, i.e., commonly-attested codeswitches were read more efficiently than those rarely-attested. In the present study, we test the distributional asymmetries of mixed NPs. Because the different combinations of mixed NPs occur at rates that vary depending on the gender of the noun and congruency between the noun and its accompanying determiner, examining this construction will lead to a more nuanced view of effects related to frequency of occurrence. Research on the processing of grammatical gender has shown that speakers are skilled at using morphosyntactic information to facilitate language processing (Dussias, Valdés Kroff, Guzzardo Tamargo, & Gerfen, 2013). In Spanish for example, adults and children as young as three years-old can anticipate the grammatical gender of a noun based on the gender information encoded on a prenominal modifier (Lew-Williams & Fernald, 2007). However, a recent eye-tracking study by Valdés Kroff, Dussias, Gerfen, Perrotti, and Bajo (2016) found that experience with codeswitching modulated the use of grammatical gender during comprehension. Using the visual world paradigm, Valdés Kroff et al. reported that whereas Spanish monolinguals could use grammatical gender as a facilitatory cue in sentence processing, Spanish-English codeswitchers only exhibited anticipatory effects in feminine-determiner conditions, which mirrored the production asymmetry between masculine and feminine gender in codeswitched speech. Taken together, these findings illustrate how production and comprehension processes are tightly linked and can adapt to individuals' codeswitching practices.

The present study

The study reported here seeks to further investigate the production-comprehension link by examining how codeswitches are processed at the neural level and whether bilinguals perform differently as a function of codeswitching experience. The first prediction concerns processing efficiency. Because distributional regularities form the basis for processing difficulty, codeswitches consistent with attested distributional patterns are more expected to bilinguals who codeswitch than those that are not, and should be easier to process. Additionally, because the constraints that language perceivers learn emerge from their prior linguistic experience, we predict variability among speakers who engage and do not engage in codeswitching. This second prediction is also in line with the Adaptive Control Hypothesis (Green & Abutalebi, 2013), which states that language control processes in bilingual speakers differentially adapt to the recurrent demands imposed by their interactional context. To date only a handful of studies have examined bilingual performance on the basis of switching behavior; those studies have reported a relationship between degree of switching languages in the daily life and non-linguistic task-switching performance (Hartanto & Yang, 2016; Prior & Gollan, 2011; Yang, Hartanto, & Yang, 2016; Yim & Bialystok, 2012). In analogy to the adaptive control hypothesis, the prediction is that comprehension processes adapt to the demands of language production accountable for codeswitching regularities.

We draw on two types of electrophysiological comparisons in two groups of Spanish-English bilinguals: one group immersed in a dual-language context with early and continued exposure to codeswitched speech and another group immersed in a single-language context with little-to-no exposure to codeswitching. It is hypothesized that the differences in the two groups' interactional contexts, and specifically regarding their codeswitching practices, will lead to differences in processing codeswitched stimuli. Specifically, differential processing is expected to occur across different types of switches (i.e., congruent gender vs. incongruent gender) but also between switches and non-switches. Examination of these manipulations will help determine the extent to which language processes are shaped by the way bilinguals use their languages.

The first comparison (congruent gender switch vs. incongruent gender switch) examines the production asymmetry in mixed NPs. If codeswitchers are sensitive to the production choices of their discourse environment, then codeswitches that are consistent with distributional patterns (i.e., gender congruent switches: '<u>el</u> fork', "the$_{MASC}$ fork$_{MASC}$" and '<u>la</u> spoon', "the$_{FEM}$ spoon$_{FEM}$", or gender incongruent switches preceded by masculine determiners: '<u>el</u> spoon', "the$_{MASC}$ spoon$_{FEM}$") are expected to be processed more efficiently than rarely-attested codeswitches (i.e., gender incongruent switches preceded by feminine determiners: '<u>la</u> fork', "the$_{FEM}$ fork$_{MASC}$"). Non-codeswitchers are not expected to show sensitivity to this manipulation. The second comparison (non-switch vs. switch) examines whether switching difficulties associated with the processing of codeswitched language are modulated by codeswitching experience. While effects of switching are expected in general for non-codeswitchers, regardless of the kind of switch, such effects should be reduced or absent for codeswitchers if these switches are consistent with attested distributional patterns.

In the following section, we present the results of an ERP experiment examining the consequences of the differences in distributional patterns for the comprehension of codeswitched sentences. Given codeswitchers' extensive experience with codeswitching regularities, their comprehension of codeswitched sentences should mirror patterns found in naturalistic production.

Experiment 1

Method

Participants

Two groups of Spanish-English bilinguals were recruited. The first group (non-codeswitchers, N = 22) were students from the University of Granada, Spain. This population was chosen because bilinguals in this region normally grow up with little-to-no exposure to codeswitching (Guzzardo Tamargo, Valdés Kroff, & Dussias, 2015). The second group of participants (codeswitchers, N = 22) was comprised of speakers from Hispanic countries who had immigrated to the United States (U.S.) in early childhood and were raised in established Spanish-English codeswitching communities in the U.S. and in Puerto Rico. Participants were students recruited from a large U.S. institution and had been living in the U.S. at the time of testing. All participants gave informed consent and were paid $10 per hour for their participation.

Participants were native Spanish speakers, who acquired Spanish at birth and English either simultaneously or in childhood. To assess linguistic proficiency, participants completed the Spanish version of the LEAP-Q language background questionnaire (Marian, Blumenfeld, & Kaushanskaya, 2007), and performed verbal fluency tasks in both languages as a measure of bilinguals' vocabulary knowledge and lexical access in production. The full set of participant characteristics is summarized in Table 1.

Language history questionnaire

Within-group comparisons of participants' proficiency levels in both languages showed significant differences for non-codeswitchers but not for codeswitchers. Non-codeswitchers rated themselves as more proficient in Spanish than in English ($t(20) = 7.84, p < 0.001$) whereas codeswitchers perceived themselves to be more balanced in their two languages ($p = 0.63$). In addition to participants' proficiency self-ratings, there were differences in reported linguistic environments for each bilingual group. At the time of testing, non-codeswitchers were immersed in a predominantly Spanish-speaking environment (Spain) whereas codeswitchers were immersed in a predominantly English-speaking environment (U.S.). Codeswitchers reported a longer immersion experience in an English-speaking environment ($t(22.49 = -5.45, p < 0.001$) and also reported codeswitching more frequently ($t(41.65) = -3.09, p < 0.004$) than non-codeswitchers. We capitalized on the distinction between the two contexts of language use on the grounds that bilinguals may show different patterns of conversational exchanges. Drawing on the Adaptive Control Hypothesis (Green & Abutalebi, 2013), we predict that bilinguals' differential interactional contexts would modulate performance on measures of language dominance and proficiency.

Verbal fluency

All participants performed the verbal fluency task in the L1 (Spanish) first and then in the L2 (English). In this task, participants are asked to generate as many exemplars as possible that belong to a semantic category within a designated time limit. Previous studies focusing on the effects of immersion on the native language have shown a decline in the accessibility to L1 words in an L2 environment (Baus, Costa, & Carreiras, 2013). For example, a study by Linck, Kroll, and Sunderman (2009) found that L2-immersed second language learners produced a smaller number of exemplars in their L1 than classroom learners without immersion experience, suggesting that the L1 was attenuated in the L2 environment.

Four different categories (e.g., clothing) were used in each language. If L2 immersion increases the retrieval demands of L1 production due to inhibition (e.g., Green, 1998), codeswitchers should produce fewer exemplars in Spanish than non-codeswitchers given their reported differences in language exposure. Between-group comparisons of participants' total number of exemplars revealed significant differences: non-codeswitchers generated more exemplars in Spanish than codeswitchers ($t(41.72) = 5.22, p < 0.001$). However, no differences between groups were observed in the total number of generated English exemplars ($t(35.49) = -1.32, p = 0.20$), indicating that both groups are matched with respect to L2 verbal ability. In summary, the two groups are proficient in both languages and display differences that are expected given their linguistic experience.

Materials and design

Experimental stimuli were pairs of preamble-target sentences (see Table 2, for a sample trial). A preamble-target pair consisted

Table 1
Participant characteristics.

	Non-codeswitchers			Codeswitchers		
	Valid *N*	*M*	*SD*	Valid *N*	*M*	*SD*
Age (in years)	22	23.8	3.1	21	21.0	2.5
English AoA (in years)	22	6.2	1.0	21	4.9	3.1
L2 Immersion (in years)	22	1.3	2.3	21	12.3	9.0
Self-rating: Spanish (/10)	21	9.8	0.4	21	9.1	1.0
Self-rating: English (/10)	22	8.5	0.6	21	9.2	0.8
Verbal Fluency: Spanish	22	56.9	9.2	22	44.8	10.0
Verbal Fluency: English	22	44.4	5.7	22	47.4	9.0

Note. Means and standard deviations for age, subjective language proficiency self-ratings, and verbal fluency (total number of tokens) measures are shown. All values represent raw, non-standardized scores.

of a sentence that provided supporting context (e.g., 'María está setting the table before the invited guests arrive', "Mary is setting the table before the invited guests arrive") followed by a sentence that contained a target codeswitch involving a Spanish determiner and an English noun (e.g., 'Su mamá le pidió que colocara **el/la fork** next to every dish', "Her mother asked her to put the$_{\text{MASC/FEM}}$ fork next to every dish").

Preamble-target pairs were constructed to be as natural as possible and covered a range of topics. Each preamble and target sentence in a pair began in Spanish and switched into English to induce a bilingual language mode (Grosjean, 2001). Switches in preamble sentences included a variety of syntactic sites (e.g., at the auxiliary-verb site, at the main verb, or at the prepositional phrase) that have been shown in previous analyses of bilingual corpora to participate frequently in codeswitching. The target sentence of the pair switched into English at a target noun (switch conditions) or continued in Spanish (non-switch conditions). Nouns were immediately preceded by either a masculine or feminine determiner. The gender of the target nouns (or the gender of its translation equivalent in Spanish) was manipulated such that it either matched its accompanying article (congruent condition, as in 'el fork', "the$_{\text{MASC}}$ fork$_{\text{MASC}}$") or it did not match the accompanying article (incongruent condition, as in 'el spoon', "the$_{\text{MASC}}$ spoon$_{\text{FEM}}$"). Noun phrases in non-switch conditions were always congruent. Each participant saw 40 trials per condition resulting in a total of 240 unique trial sextets (see supplementary materials for complete list of experimental stimuli).

The 240 unique trial sextets were distributed across six experimental lists in a Latin square design, such that each list contained only one condition of each sextet. Each list contained 40 trials per condition, and all target words were counterbalanced across conditions. Experimental sentences were pseudo-randomized among 80 fillers. Filler trials consisted of similar preamble-target trials but contained codeswitches at syntactically different points not reported here. Target word pairs ($N = 240$) were matched in orthographic word length and word frequency across and between languages using the CLEARPOND database (Marian, Bartolotti, Chabal, & Shook, 2012). Lexical characteristics are summarized in Table 3.

Additionally, to ensure that target words across conditions were equally plausible as continuations of the same preamble, cloze probabilities were obtained for masculine and feminine targets in an offline norming task. To this end, the 240 preamble-target stimuli were divided into four lists of 60 trials, with two versions of counterbalancing contexts truncated after a masculine determiner and contexts truncated after a feminine determiner. Each version contained an equal number of masculine and feminine trials. Spanish-English bilingual volunteers, who did not participate in the experiment, were asked to fill in the blanks with the best word or phrase to complete each sentence. Individual participants saw only one version of sentences with each list normed by 22–26 participants.

Cloze probability was calculated as the proportion of individuals choosing to complete sentence contexts with the target word. Word cloze ranged from 0% to 93%. Overall, cloze probability for feminine targets was greater than for masculine targets ($t(239) = -2.24$, $p = 0.03$). However, there was no difference between the proportion of switched matched responses that were masculine-gendered ($N = 68$) and the proportion of switched matched responses that were feminine-gendered ($N = 53; \chi^2 = 1.62, df = 1, p = 0.20$). Mean and standard deviations of the target nouns are summarized in Table 4.

Procedure

During ERP recording, participants were seated in a comfortable armchair in front of a computer screen in a sound-attenuated room with dimmed lighting. Participants were instructed to relax and minimize eye blinks and movements, and to read each sentence as normally as possible. Before the experiment, participants were presented with a six-trial practice block to familiarize them with the trial sequence.

Each trial was preceded by a fixation cross for 1000 ms, followed by a preamble sentence. The preamble was fully displayed until participants pressed a button. After a fixation cross for 300 ms, the target sentence was presented word-by-word using rapid serial visual presentation. Each word of the target sentence appeared on the screen for 300 ms followed by a 350 ms interstimulus interval. The target noun was always in sentence-medial position. Sentences were presented in lower case letters except for proper names and the first letter of the first word. Sentence ending words appeared with a period. This screen was followed by a picture asking for a relatedness comparison. Participants were instructed to respond by pressing "yes" or "no" buttons to pictures that were respectively congruent or incongruent to the preceding preambles-target sentences. Non-codeswitchers ($M = 0.96, SD = 0.02$) were significantly more accurate on comprehension questions than codeswitchers ($M = 0.93, SD = 0.07; t(24.08) = 2.09, p = 0.047$). Despite this difference, as the means show, both groups were highly accurate in the comprehension questions.

EEG recording and analysis

The continuous electroencephalogram (EEG) was recorded from 32 electrodes mounted in an elastic cap (Quick-cap, Neuroscan Inc.) and a Synamps2 amplifier (Neuroscan, Inc.) with a 24-bit analog to digital conversion (online sampling rate: 500 Hz; 0.05–100 Hz band-pass filter). Electrode impedances were kept below 5 KΩ. The same equipment was used in both U.S. and Spain testing locations. Because the data were recorded in different laboratories, and because one of the main goals of our study was to examine potential differences between the two groups as a function of codeswitching experience, we followed Kaan, Kirkham, and

Table 2
Experiment 1 conditions.

Determiner gender	Noun gender	NP congruency	Switch	Target NP
Masculine	Masculine	Congruent	Yes	el fork
Feminine	Masculine	Incongruent	Yes	la fork
Feminine	Feminine	Congruent	Yes	la spoon
Masculine	Feminine	Incongruent	Yes	el spoon
Masculine	Masculine	Congruent	No	el tenedor
Feminine	Feminine	Congruent	No	la cuchara

Table 3
Target word characteristics.

Language	Gender	Sample target word	Word frequency		Orthographic length	
			M	*SD*	*M*	*SD*
Spanish	Masculine	Tenedor	1.10	0.67	6.92	2.15
	Feminine	Cuchara	1.18	0.65	6.79	1.98
English	Masculine	Fork	1.18	0.62	6.49	2.19
	Feminine	Spoon	1.23	0.59	6.19	2.22

Note. Frequencies are given as logarithm to base 10. Orthographic length is measured in the number of letters in the orthographic form.

Table 4
Mean and standard deviation cloze probability for masculine- and feminine-gendered nouns.

Noun gender	Sample cloze	Number of items	Cloze probability	
			M	*SD*
Masculine	Tenedor/fork	240	0.09	0.13
Feminine	Cuchara/spoon	240	0.12	0.16

Wijnen (2016) and conducted separate analyses for the two groups; as a result, any differences between the groups are comparatively discussed.

During recording, the electrodes were referenced to a vertex electrode (REF) for non-codeswitchers and to the right mastoid for codeswitchers. For both groups, the grounding electrode (GND) was mounted on the forehead. Blinks and eye-movements were measured by placing bipolar pairs of vertical (VEOG) electrodes above and beneath the left eye and lateral (HEOG) electrodes at the outer canthi of both eyes. Continuous EEG data were analyzed using ERPLab (López-Calderón & Luck, 2014). Prior to offline averaging, trials contaminated by muscle and ocular artifacts were rejected using an amplitude threshold of ±100 μV and blink rejection procedures. Data were re-referenced to the averaged mastoids.

Averaged ERPs were computed for artifact-free trials and were filtered with a Gaussian low-pass filter (25 Hz half-amplitude cut-off). On average, 15.7% of trials were rejected due to the presence of artifacts. There were no significant differences in the number of trials rejected in each condition or across groups ($Fs < 2$). Grand averages were then computed for each condition using the filtered data. Based on previous literature and visual inspection of the waveforms, three time windows were selected to examine components of interest. First, a 300–500 ms time window was chosen to capture the N400 component. Second, a 500–700 ms time window was chosen to correspond to the P600 component. Third, a 230–330 ms time window was chosen to capture a positivity observed at anterior sites. Grand mean amplitudes of critical target words corresponding to these time windows were calculated for all electrodes for each condition.

Repeated measures ANOVAs were conducted on the mean amplitude of the target nouns corresponding to the 300–500 ms (N400), 500–700 ms (P600), and 230–330 ms (frontal positivity) time windows. Each rANOVA used condition and electrode as within-subject factors. For switch vs. switch comparisons, we focused our statistical analysis on midline electrodes (Fz, Cz, Pz, Oz) in the 300–500 and 500–700 ms following Rossi, Kroll, and Dussias (2014). For switch vs. non-switch comparisons, rANOVAs were conducted on anterior electrode sites (FP1/FP2, F7/F8, F3/F4, Fz) in the early time window of 230–330 ms. See supplementary materials for additional analyses conducted in other head regions. We will only report effects involving condition as general hemisphere and electrode site differences are to be expected. The Greenhouse-Geisser correction with more than 1 degree of freedom was used in all relevant analyses. Partial eta squared was calculated to determine the effect sizes for both significant and non-significant comparisons.

Results

Below we report the results for the three different time windows to compare the processing across different types of mixed NPs (congruent gender switch vs. incongruent gender switch) as well as the processing of mixed NPs relative to unilingual noun phrases (switch vs. non-switch) across our two groups of participants.

Congruent-gender switch vs. incongruent-gender switch

Repeated measures ANOVAs were conducted in the 300–500 ms and 500–700 ms time windows, including the within-subject factors of condition (congruent gender, incongruent gender) and of electrode for the midline column (Table 5). The ERPs for these comparisons are displayed in Fig. 1 for masculine target nouns and in Fig. 2 for feminine target nouns.

Masculine target nouns (el "fork" – la "fork"). As illustrated in Fig. 1, for non-codeswitchers, no main effects of switch were observed in either the 300–500 ms or the 500–700 ms time windows. For codeswitchers in the 300–500 ms time window, there was a main effect of switch condition at the midline with a larger negativity for

Table 5
Main effects of condition (congruent-gender switch, incongruent-gender switch) for the midline column in Experiment 1.

Statistical comparison	Time window (ms)	Group 1: Non-codeswitchers			Group 2: Codeswitchers		
		$F(1,21)$	p	η_p^2	$F(1,21)$	p	η_p^2
Masculine nouns	300–500	1.45	0.242	0.07	19.77	**0.000**	0.49
	500–700	0.29	0.596	0.01	7.40	**0.013**	0.26
Feminine nouns	300–500	0.50	0.49	0.02	0.14	0.72	0.01
	500–700	12.72	**0.002**	0.38	0.0075	0.397	0.03

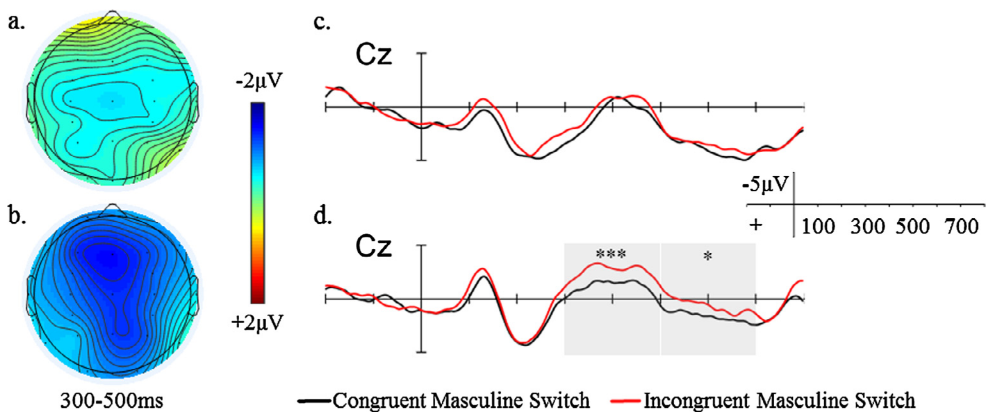

Fig. 1. Experiment 1 ERPs to congruent and incongruent masculine switch conditions. ERPs for congruent and incongruent masculine switch conditions. Left: ERP scalp topography illustrating the difference in N400 effect size between a. non-codeswitchers and b. codeswitchers from 300 to 500 ms. Difference waves were calculated by subtracting mean congruent target switch amplitudes from mean incongruent target switch amplitudes. Scale is from −2 (blue) to +2 (red) microvolts. Right: ERP waveforms for c. non-codeswitchers and d. codeswitchers from the representative electrode Cz for congruent (black) and incongruent (red) masculine switch conditions. Negative is plotted up. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

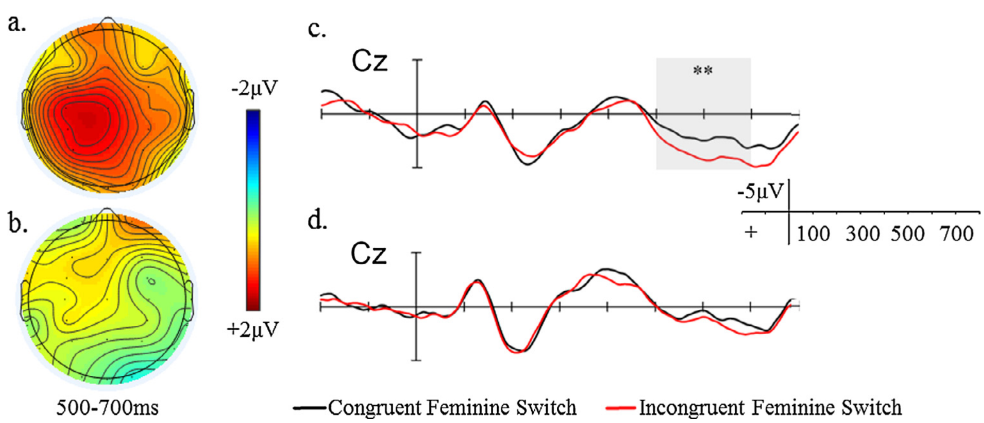

Fig. 2. Experiment 1 ERPs to congruent and incongruent feminine switch conditions. ERPs for congruent and incongruent feminine switch conditions. Left: ERP scalp topography illustrating the difference in P600 effect size between a. non-codeswitchers and b. codeswitchers from 500 to 700 ms. Difference waves were calculated by subtracting mean congruent target switch amplitudes from mean incongruent target switch amplitudes. Scale is from −2 (blue) to +2 (red) microvolts. Right: ERP waveforms for c. non-codeswitchers and d. codeswitchers from the representative electrode Cz for congruent (black) and incongruent (red) masculine switch conditions. Negative is plotted up. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

the incongruent switch condition relative to congruent switch condition. This effect remained significant in the 500–700 ms time window.

Feminine target nouns (la "spoon" – el "spoon"). For non-codeswitchers, no differences were obtained at the 300–500 ms time window.[2] At the 500–700 ms time window, there was a main effect of switch at the midline driven by a larger positivity for the incongruent switch condition relative to the congruent switch condition. For codeswitchers, no main effects of switch condition were observed in either the 300–500 ms or 500–700 ms time windows.

Switch vs. non-switch comparisons

Repeated-measures ANOVAs were conducted in the 230–330 ms time window including the within-subject factors of condition (switch, non-switch) and electrode site for frontal electrode sites (Table 6). The ERPs for these comparisons for masculine and feminine target nouns are displayed in Figs. 3 and 4 respectively.

Congruent masculine target nouns (el "fork" – el "tenedor"). In the non-codeswitching group, there was a main effect of switch at

[2] Additional analyses at the 200–400 ms time window were conducted but no significant effects were observed.

Table 6
Main effects of condition (switch, non-switch) for frontal electrode sites in Experiment 1.

Statistical comparison	Time window (ms)	Group 1: Non-codeswitchers			Group 2: Codeswitchers		
		$F(1,21)$	p	η_p^2	$F(1,21)$	p	η_p^2
Masculine gender							
Congruent NPs	230–330	10.09	**0.005**	0.33	2.54	0.126	0.11
Incongruent NPs	230–330	4.57	**0.044**	0.18	1.21	0.283	0.06
Feminine gender							
Congruent NPs	230–330	7.01	**0.015**	0.25	0.01	0.946	0.00
Incongruent NPs	230–330	12.24	**0.002**	0.37	0.15	0.705	0.01

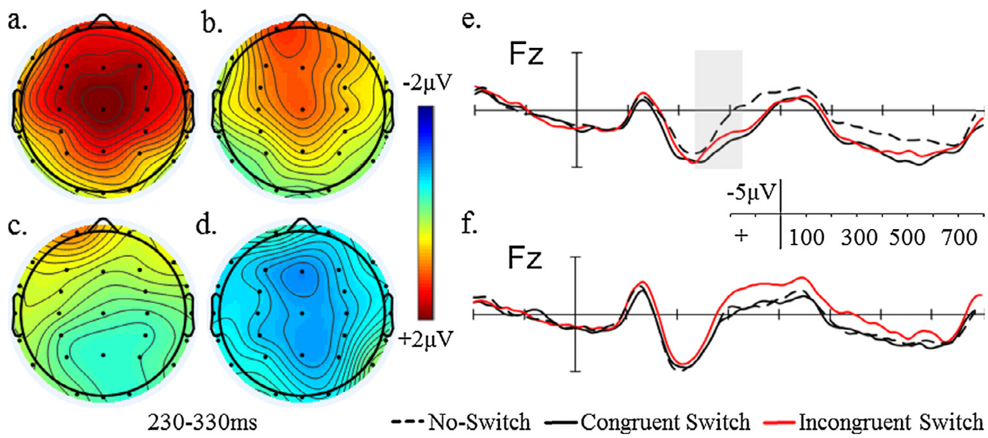

Fig. 3. Experiment 1 ERPs to masculine switch and non-switch conditions. ERPs for masculine switch and non-switch conditions. Left: ERP scalp topography illustrating the size of the switch effect between a./b. non-codeswitchers and c./d. codeswitchers from 230 to 330 ms. Difference waves a. and c. were calculated by subtracting mean congruent switch amplitudes from mean non-switch amplitudes. Difference waves b. and d. were calculated by subtracting mean incongruent switch amplitudes from mean non-switch amplitudes. Scale is from −2 (blue) to +2 (red) microvolts. Right: ERP waveforms for e. non-codeswitchers and f. codeswitchers from the representative electrode Fz for non-switch (dashed) and congruent (black) and incongruent (red) masculine switch conditions. Negative is plotted up. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

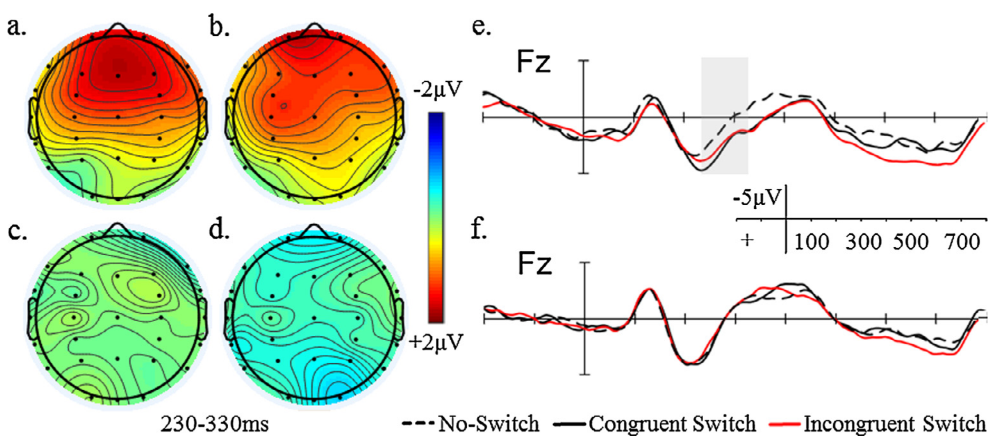

Fig. 4. Experiment 1 ERPs to feminine switch and non-switch conditions. ERPs for feminine switch and non-switch conditions. Left: ERP scalp topography illustrating the size of the switch effect between a./b. non-codeswitchers and c./d. codeswitchers from 230 to 330 ms. Difference waves a. and c. were calculated by subtracting mean congruent switch amplitudes from mean non-switch amplitudes. Difference waves b. and d. were calculated by subtracting mean incongruent switch amplitudes from mean non-switch amplitudes. Scale is from −2 (blue) to +2 (red) microvolts. Right: ERP waveforms for e. non-codeswitchers and f. codeswitchers from the representative electrode Fz for non-switch (dashed) and congruent (black) and incongruent (red) feminine switch conditions. Negative is plotted up. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

frontal sites with a larger positive deflection for the switch condition relative to the non-switch condition. For codeswitchers, no effects of switch were observed.

Incongruent masculine target nouns (la "fork" – el "tenedor"). For non-codeswitchers, there was a main effect of switch at frontal sites with a larger positivity for the switch condition relative to the non-switch condition. For codeswitchers, no main effects were observed.

Congruent feminine target nouns (la "spoon" – la "cuchara"). For non-codeswitchers, there was a main effect at frontal sites with the switch condition being more positive than the non-switch condition. For codeswitchers, no main effects of switch were observed.

Incongruent feminine target nouns (el "spoon" – la "cuchara"). For non-codeswitchers, there was a main effect of condition at frontal sites with the switch condition being more positive than the non-switch condition. For codeswitchers, no main effects were observed.

To summarize, the two groups of bilinguals differed in their processing of codeswitched sentences. While non-codeswitchers were insensitive to the congruency and gender of switched target nouns, codeswitchers demonstrated an asymmetry in how they process masculine vs. feminine nouns. Specifically, codeswitchers exhibited an N400 effect to masculine targets in incongruent noun phrases, suggesting greater difficulty in lexical integration. Furthermore, we found that only non-codeswitchers displayed an early positivity for switch vs. non-switch comparisons. By looking at the effect sizes, it becomes clear that the findings of study were not influenced by low power or sample sizes. That is, while significant results had large effect sizes (i.e., η_p^2 range from 0.18 to 0.49; Stevens, 2012), the effect sizes for results in which differences were absent were much smaller (i.e., η_p^2 range from 0.00 to 0.11). Therefore, non-significant differences were considered true negatives. Altogether, the findings of the current study provide a novel source of evidence for how bilinguals process codeswitched language.

A potential methodological caveat in the switch vs. non-switch comparison is that the analysis involves different languages; hence, it could be argued that the differences evoked in the ERP events are not due to the critical experimental manipulation, but rather to differences in the characteristics of the words themselves. To make the electrophysiological comparison of different target words feasible, it is important to ascertain whether brain signatures of bilinguals' language systems (e.g., fork$_{ENG}$ vs. tenedor$_{SPAN}$) are underlyingly similar to one other. While there is no evidence that specific language characteristics may lead to a modulation of electrophysiological parameters (Kutas & Federmeier, 2011), the N400 has been found to be sensitive to an individual's linguistic proficiency. For example, evidence from studies using word-level semantic categorization tasks have found language effects in the form of differential peak latencies and mean amplitudes of the N400 component (e.g., Aparicio et al., 2012; Midgley, Holcomb, & Grainger, 2009). Therefore, one possibility is that non-codeswitchers are more sensitive to cross-language comparisons relative to codeswitchers because they are relatively unbalanced in their two languages. To safeguard against this caveat and assess any differential language effects, we conducted a control study (Experiment 2), during which we recorded the EEG of Spanish-English bilinguals as they read unilingual translation-equivalent sentences in both of their languages.

Experiment 2

Method

Participants

The control experiment was performed on the same groups of participants in Experiment 1. Nineteen out of the 22 non-codeswitchers and 19 out of the 22 codeswitchers accepted our invitation to participate in the control experiment.

Materials and design

Two hundred and forty sentences were constructed using the same masculine-feminine target pairs from the previous ERP study (see Table 7, for a sample trial). Experimental trials were translation-equivalent sentences presented in either Spanish or English. The syntactic structure of the sentences did not differ across languages. In Spanish conditions, the gender of the target noun always matched its accompanying determiner (masculine condition, as in 'el tenedor'/"the$_{MASC}$ fork$_{MASC}$" or feminine condition, 'la cuchara'/"the$_{FEM}$ spoon$_{FEM}$"). This resulted in 240 unique trial quartets (see supplementary materials for complete list of experimental stimuli). Sentences were distributed across four experimental lists in a Latin square design, such that each list contained only one condition of each quartet. Stimuli were blocked by language and the order of the two blocks was counterbalanced across participants.

Table 7
Sample quartet from Experiment 2.

Language	Noun Gender	Sample Sentence
English	Masculine[a]	The woman placed the **fork** on the table.
English	Feminine[a]	The woman placed the **spoon** on the table.
Spanish	Masculine	La mujer colocó el **tenedor** en la mesa.
Spanish	Feminine	La mujer colocó la **cuchara** en la mesa.

[a] *Note*. The gender of English target nouns is based on the gender of their Spanish translation equivalent.

Procedure

Each trial consisted of the following events: a trial began with the presentation of a fixation cross for 1000 ms, followed by a target sentence presented word-by-word. Each word of the target sentence appeared in the middle of the screen for 300 ms followed by a 350 ms inter-stimulus interval. Sentences were presented in lower case letters except for proper names and the first letter of the first word. Sentence-ending words appeared with a full stop. This screen was followed by a picture asking for a relatedness comparison. Participants were instructed to respond by pressing "yes" or "no" buttons to pictures that were respectively congruent or incongruent to the preceding sentences.

EEG recording and analysis

The EEG recording and analysis is the same as in Experiment 1.

Results

Repeated measures ANOVAs were conducted at the 230–330 ms time window with within subject factors of language (English, Spanish) and electrode site for frontal sites and at the 300–500 ms and 500–700 ms time windows for the midline column. See the supplementary materials for additional analyses conducted in other head regions. As shown in Fig. 5, for non-codeswitchers and codeswitchers, analysis of mean amplitudes revealed no apparent main effects of language in the three time windows.

Overall, the results of Experiment 2 confirm that despite the differences at the level of the word form, translation-equivalent stimuli can be electrophysiologically compared during sentence reading. The absence of language effects also suggests that both groups were highly proficient in both languages.

The goal of Experiment 1 was to assess bilinguals' sensitivity to codeswitching regularities as a function of their linguistic experience. Because it was hypothesized that bilinguals' sensitivity to mixed NPs derives from how speakers use their languages, a corpus elicitation task (Experiment 3) was conducted to directly compare participants' production choices and, in doing so, substantiate the comprehension data. The expectation is that although both groups may alternate between languages, we should observe

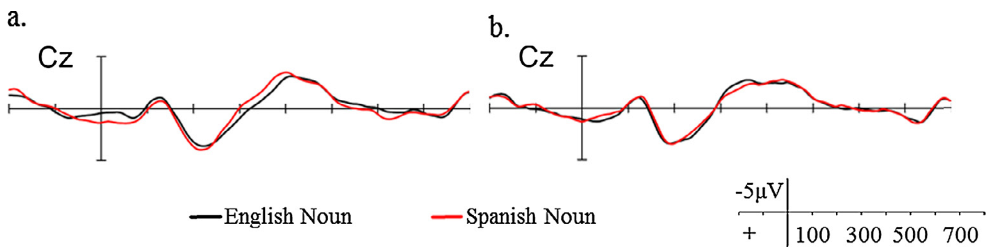

Fig. 5. Experiment 2 ERPs to English and Spanish conditions. ERP waveforms for a. non-codeswitchers and b. codeswitchers from the representative electrode Cz for English (black) and Spanish (red) conditions. Negative is plotted up. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

higher rates of codeswitching within the noun phrase in codeswitchers but not in non-codeswitchers.

Experiment 3

Method

The goal of the corpus elicitation study was to examine non-codeswitchers' and codeswitchers' language use. To assess codeswitching ability, a map task adapted from Anderson et al. (1991) was developed in which pairs of director-matcher speakers verbally communicated to reproduce on the matcher's map a set of images printed on the director's map. For each map, directors and matchers had 2.5 min to complete each description. This task (labeled the codeswitching map task), involves a series of unscripted dialogues between two bilingual speakers who are free to use either or both of their languages in a game-like fashion. Conversational partners were composed of the participant and a bilingual confederate, who regularly codeswitches. While the confederate's utterances were unscripted, both languages were introduced during the practice to induce a bilingual language mode. The corpus includes approximately 12–15 min conversations averaged over six different maps from each participant. The confederate gives directions and the participant matches the objects during the practice map which had a 1-min designated time limit. Roles are reversed during the remainder of the task (maps 2–6).

Participants

The same Spanish-English bilinguals from Experiment 1 performed the codeswitching map task.

Materials and design

The codeswitching map task consisted of a set of six maps that were presented using PowerPoint's editing view (see Fig. 6). This presentation mode was chosen so that the matcher could select the objects and drag them to the director's specified coordinates. Director and matcher maps differed only in terms of the way the objects were arranged on the screen. A timer was set for the designated interval (1 min for the practice slide, and 2.5 min for each of the remaining slides) and placed within clear view of both the participant and the confederate.

To maximize the use of noun phrases, a series of manipulations were applied. Maps contained background objects that were fixed. Objects were presented in color to elicit more detailed descriptions (e.g., 'a red curtain'). Moveable objects were placed in reference to fixed objects exerting the need to describe them in terms of their spatial arrangement. Each map contained a balanced number of nouns with masculine grammatical gender and nouns with feminine grammatical gender. To exert pressure on the task, the time was kept constant, but the number of objects increased by 8 after each map. Masculine and feminine objects were matched on phonological word length and lexical frequency, within each language using the CLEARPOND database (Marian et al., 2012). Mean and standard deviations of the target nouns are summarized in Table 8.

Fig. 6. A visual pane from the codeswitching map task.

Procedure

The task was administered by a proficient bilingual researcher. In each session, participant and confederate pairs were tested opposite each other both with a laptop in front of them, and they were informed that their conversation would be recorded. To minimize the need for self-monitoring, participants were told that the goal of the task was for the matcher to map objects on a screen following director instructions, and that they should communicate with each other informally in whichever manner they found the most comfortable. Importantly, no language restrictions were imposed so speakers were free to use which ever language they chose and could alternate between them at will. Task sessions were recorded using a Marantz Professional Solid State Recorder PMD660 and a Shure SM57 desk-mounted microphone. The task took on average approximately 20 min to complete.

Extraction and coding procedure

Participants' noun phrases were transcribed using ELAN (EUDICO Linguistic Annotator software; Sloetjes & Wittenburg, 2008) which is developed and distributed by the Max Plank Institute for Psycholinguistics, and is made publicly available online at <https://tla.mpi.nl/tools/tla-tools/elan/>. Identification and extraction of noun phrases were conducted by the first author and research assistants who were native speakers of Spanish and were highly proficient in English. Reliability of data extraction

Table 8
Codeswitching map task item characteristics.

Language	Gender	Sample objects	Word frequency		Phonological length	
			M	SD	M	SD
Spanish	Masculine	Zapato	0.92	0.57	6.7	2.10
	Feminine	Pluma	1.11	0.57	6.2	1.82
English	Masculine	Shoe	1.11	0.75	4.9	1.83
	Feminine	Feather	1.13	0.50	4.7	1.76

Note. Frequencies are given as logarithm to base 10. Phonological length is measured in phonemes.

Table 9
Participants' number and proportion of noun phrase utterances per condition in the codeswitching map task.

Noun phrase type	Example noun phrase	Group 1: Non-codeswitchers		Group 2: Codeswitchers	
		N	%	N	%
Spanish noun phrases					
Masculine noun	el tenedor	1810	(0.36)	1719	(0.34)
Feminine noun	la cuchara	1915	(0.38)	1631	(0.32)
English noun phrases					
Masculine noun	the fork	692	(0.14)	576	(0.11)
Feminine noun	the spoon	611	(0.13)	517	(0.10)
English to Spanish mixed NPs					
Masculine noun	the tenedor	5	(0.00)	1	(0.00)
Feminine noun	the cuchara	11	(0.00)	6	(0.00)
Spanish to English mixed NPs					
Congruent masculine noun	el fork	**23**	**(0.00)**	**318**	**(0.06)**
Incongruent masculine noun	la fork	0	(0.00)	5	(0.00)
Congruent feminine noun	la spoon	6	(0.00)	22	(0.00)
Incongruent feminine noun	el spoon	**7**	**(0.00)**	**269**	**(0.05)**
Total number of noun phrases		5080	(1.0)	5064	(1.0)

was checked, and any disagreements were resolved by group consensus between three coders. Every instance of a noun phrase was recorded as a unique token and was coded for the following factors: language (i.e., unilingual Spanish, unilingual English, or mixed), gender (i.e., masculine or feminine), and gender agreement (i.e., congruent, incongruent). The gender of English nouns was coded based on the gender of its Spanish translation equivalent. Bare nouns and NPs that began with a Spanish determiner (or its English equivalent) that did not mark for grammatical gender (e.g., su perro, his/her$_{\o}$ dog) were excluded.

Results

The participants produced 10,144 noun phrases, consisting of 7075 unilingual Spanish noun phrases, 2396 unilingual English noun phrases, and 673 mixed noun phrases. Table 9 presents the number and proportion of noun phrases per condition. Visual inspection of the distribution shows that non-codeswitchers produced far less mixed NPs than codeswitchers. Furthermore, codeswitchers demonstrated the reported gender asymmetry in that the overwhelming number of switched nouns were preceded by Spanish masculine determiners. Although, English-to-Spanish codeswitches were not tested in the ERP study, quantification of these types of mixed noun phrases also mirrored the report asymmetric distribution found in naturalistic corpora (e.g., Valdés Kroff, 2016).

The data were analyzed using mixed-effects logistic regression models with random intercepts for participants and items (Baayen, Davidson, & Bates, 2008) using the lme4-package (version 1.1-7, Bates, Maechler, Bolker, & Walker, 2015) in R version 3.1.2 (R Development Core Team, 2014). Mixed effects logistic regression analyses are ideal for categorical dependent variables that have a binary outcome because they perform analyses on the participants' individual responses rather than mean responses per condition (Jaeger, 2008). The goal of the analysis was to test which factors promoted the likelihood of codeswitching within the noun phrase to validate the division between the two bilingual groups, but also confirm the distributional patterns that were examined in Experiment 1.

In the model, the dependent variable was presence or absence of a codeswitch (switch = 1, non-switch = 0), and responses that contained a switch were set as the reference level.[3] Factors were treatment coded such that positive coefficients would reflect an increase in the likelihood of a switch.

Group

Crucially, this factor will allow us to test any differences between non-codeswitchers and codeswitchers ($n = 5064$). Following the hypothesis that production choices adapt as a function of interactional context, codeswitchers should codeswitch more frequently than non-codeswitchers. Furthermore, given the results of Experiment 1, it is expected that codeswitchers' utterances reflect the mixed NP asymmetry.

Determiner language

For every noun phrase, the language of the determiner of the noun phrase was coded as English ($n = 2419$) or Spanish ($n = 7725$). This factor was included to test participants' own language choices as predictors for switching direction. While this factor was exploited in Experiment 1, it was included as part of the variable context in the production analysis following the usage-based principle of accountability (Labov, 1972). Codeswitchers

[3] Because our outcome is binary, unilingual English and unilingual Spanish noun phrases were analyzed together.

are expected to switch primarily from Spanish to English following the documented patterns found in naturalistic data.

Gender of the noun

For every noun phrase, the gender of the noun was coded as masculine ($n = 5,149$) or feminine ($n = 4,995$). For English nouns, grammatical gender was coded based on the gender of its Spanish translation equivalent. This predictor allows us to test the potential grammatical gender bias on the likelihood of codeswitching.

We first generated a model containing only by-participant and by-item random intercepts and then followed including all predictors and their interactions as fixed factors. This model was then reduced by removing non-significant predictors and interactions in stepwise manner. Pruned models were compared based on log-likelihood ratios using the anova function (Fox & Weisberg, 2011).

Because the gender of the noun did not significantly boost the likelihood of codeswitching, it was removed from the final model. The results of the final mixed logistic regression model are given in Table 10 (see supplementary materials for model details).

The analysis examined which factors promoted the likelihood of codeswitching within the noun phrase. There was a main effect of group: codeswitchers were more likely to codeswitch than non-codeswitchers. This effect is depicted in Fig. 7.

There was also a main effect of determiner language such that Spanish determiners were associated with an increased probability of a codeswitched noun more so than English determiners. The interaction between group and determiner language indicated that the codeswitching preferences differ between groups. While non-codeswitchers showed no preference in terms of switching direction, codeswitchers preferred switching from Spanish to English (e.g., 'el fork', "the$_{SPAN}$ fork$_{ENG}$"). The interaction term could also be driven by the robust differences in the number of mixed NPs produced in each group.

Additional analysis coding for determiner gender (i.e., masculine or feminine) and congruency (i.e., gender congruent or gender incongruent) factors was untenable due to the relatively low number of tokens per factor. However, tests of proportions of codeswitchers' mixed NPs revealed a preference in using masculine gendered determiners when switching into an English noun ($\chi^2 = 508.93,\ df = 1,\ p < 0.001$) despite equal proportions of masculine and feminine nouns in mixed NPs, ($\chi^2 = 1.565,\ df = 1,\ p < 0.211$).

We additionally conducted analyses on the confederate's utterances to identify probable baseline differences between groups in the number and type frequency of mixed noun phrases. The confederate's noun phrases were transcribed using the same extraction and coding procedure as that implemented for the participants. However, we limited our analysis to the first map in which the confederate plays the director role because it is in this map that the confederate leads the conversation. The confederate produced 1294 noun phrases, consisting of 783 unilingual Spanish noun phrases, 244 unilingual English noun phrases, and 267 mixed noun phrases. All switched nouns were preceded by Spanish masculine determiners. Table 11 presents the number and proportion of noun phrases per condition.

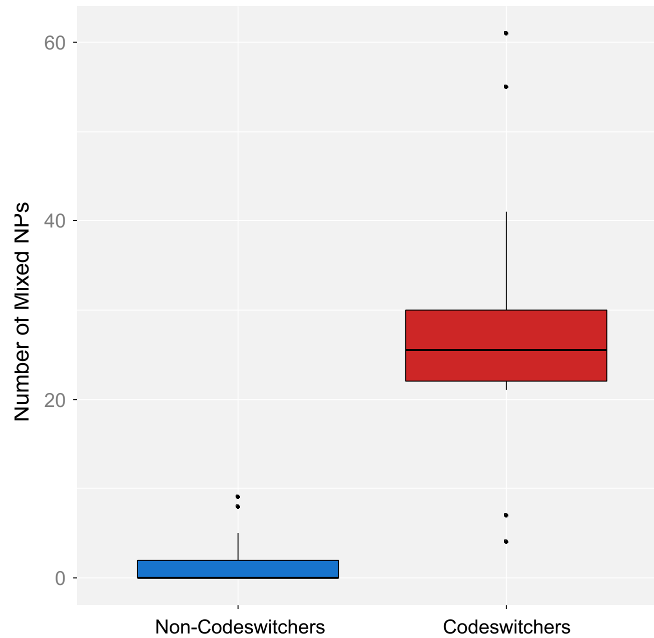

Fig. 7. Number of mixed NPs produced by non-codeswitchers and codeswitchers in the codeswitching map task. The box plot displays the data points for the individual participants. Non-codeswitchers produced on average <1% of mixed NPs. Codeswitchers produced on average 11% of mixed NPs.

We fitted a mixed-effects logistic regression model with switch as the dependent variable, group as the predictor variable, and by-participant and by-item random intercepts. The results of the model are given in Table 12 (see supplementary materials for model details). The analysis yielded no observable main effect of group indicating that the baselines were stable.

Additional analysis coding for language of the determiner (Spanish or English) and gender of the determiner (i.e., masculine or feminine) were not conducted because all codeswitched utterances were preceded by Spanish masculine determiners. Tests of proportions for noun gender in mixed NPs revealed that there was no statistically significant difference between the confederate's production of masculine- and feminine-gendered nouns in either non-codeswitcher ($\chi^2 = 0.03\ df = 1,\ p = 0.86$) or codeswitcher conversations ($\chi^2 = 0.85\ df = 1,\ p = 0.36$).

In summary, the results from Experiment 3 show both quantitative and qualitative differences in the codeswitching practices of the two participant groups. While non-codeswitchers rarely switched within the noun phrase, the utterances produced by the codeswitchers patterned on regularities that emerge in naturalistic codeswitching. These results not only validate the division between the two bilingual groups, but it also allowed us to identify and confirm the distributional patterns we examined in comprehension.

Table 10
Summary of mixed logistic regression analyses for variables predicting participants' likelihood of codeswitching within the noun phrase in the codeswitching map task.

Predictor	B	SE B	z-value	p-value
(Intercept)	−4.74	0.24	−19.68	<0.001
Group	1.76	0.38	4.58	<0.001
Determiner Language	1.98	0.27	7.42	<0.001
Group x Determiner Language	3.65	0.53	6.89	<0.001

Note. The parameter estimate (B), standard error of the parameter estimate (SE B), z-value and p-value for predictor variables and their interaction. Nonsignificant predictors were not included in the table. Standard deviations of random intercept terms were 0.81 for participants and 1.43 for items.

Table 11
Confederate's number and proportion of noun phrase utterances per condition in the codeswitching map task.

Noun phrase type	Example noun phrase	Group 1: Non-codeswitchers		Group 2: Codeswitchers	
		N	%	N	%
Spanish noun phrases					
Masculine noun	el tenedor	205	(.31)	199	(.32)
Feminine noun	la cuchara	205	(.31)	174	(.28)
English noun phrases					
Masculine noun	the fork	73	(.11)	68	(.11)
Feminine noun	the spoon	61	(.09)	42	(.07)
Spanish to English mixed NPs					
Congruent masculine noun	el fork	**64**	**(.10)**	**65**	**(.10)**
Incongruent feminine noun	el spoon	**61**	**(.09)**	**77**	**(.12)**
Total number of noun phrases		669	(1.0)	625	(1.0)

Table 12
Summary of mixed logistic regression analysis for variables predicting the confederate's likelihood of codeswitching within the noun phrase in the codeswitching map task.

Predictor	B	SE B	z-value	p-value
(Intercept)	−2.86	0.51	−5.61	<0.001
Group	0.35	0.20	1.77	0.08

Note. The parameter estimate (B), standard error of the parameter estimate (SE B), z-value and p-value for predictor variables and their interaction. Nonsignificant predictors were not included in the table. Standard deviations of random intercept terms were 2.815e−05 for participants and 2.211e+00 for items.

Discussion

For many bilinguals, codeswitching is part of their everyday, whereas for others, it is an unfamiliar experience. Because adaptation to these contexts of language use may be mediated differently, we examined the comprehension and production of codeswitched speech in two groups of bilinguals from different interactional contexts. In Experiment 1, the stimuli included both commonly- and rarely-attested codeswitches found in bilingual corpora. Commonly-attested switches were those in which the translations of Spanish nouns were presented with their corresponding masculine or feminine determiners, or those in which translations of Spanish feminine nouns were presented with masculine determiners. Rarely-attested switches, on the other hand, were translations of Spanish masculine nouns presented with feminine determiners. In Experiment 3, participants' own codeswitching preferences were assessed in a production task to determine the extent to which their own speech samples could account for the differential processing strategies found in Experiment 1.

Expectation through adaptation

The comparison of different types of switches revealed different congruency processing strategies between masculine and feminine nouns, and between the two groups. Non-codeswitchers processed codeswitches involving masculine gendered nouns similarly, regardless of the congruency between the gender of determiner and the noun's analogical gender in Spanish. However, there was a congruency effect for feminine gendered nouns such that incongruent switches elicited a P600 component, likely indexing abstract rule-based processing (Tanner, McLaughlin, Herschensohn, & Osterhout, 2013). While it has previously been shown that P600s can be elicited in response to grammatical gender violations in unilingual contexts (e.g., Wicha, Moreno, & Kutas, 2004), the current findings show that at least *some* bilinguals are sensitive to violations of the analogical criterion during the online processing of the second language. For codeswitchers, on the other hand, masculine incongruent conditions elicited an N400 indicating that this type of codeswitch was more difficult to integrate relative to the more commonly-attested congruent codeswitch. This finding suggests that codeswitchers attended to the grammatical gender of both the determiner and the noun in real time during reading. The absence of the P600 in codeswitchers suggests that congruency violations of codeswitched stimuli do not reflect online grammatical processing but rather serve more as an index of probabilistic processing. Based on these findings, we argue that codeswitching bilinguals are indeed attuned to their distributional codeswitching preferences.

One issue that remains to be addressed concerns how speakers are able to extract probabilistic information and how they can use this information in comprehension. The absence of switch costs and sensitivity to distributional regularities in codeswitchers in our study are in line with the predictions of such usage-based models of language processing (e.g., the P-Chain Model: Dell & Chang, 2014; the Production-Distribution-Comprehension (PDC) model: MacDonald, 2013). According to such models, production-based distributional patterns act as probabilistic constraints which can in turn help shape the comprehension system. The PDC model proposes that speakers' linguistic choices are influenced by implicit strategies to mitigate production difficulty and are based on prior linguistic experience. Over time, these distributional patterns become widespread and customary in a community of speakers in a constraint-based fashion. In this way, comprehension difficulty is linked to the probability of upcoming information, and interpretation preferences can be traced to individuals' distributional choices as determined by production mechanisms. We extend this framework to a bilingual scenario and argue that different language contexts will induce specific habits of control over production and comprehension processes (e.g., Green & Abutalebi, 2013; Green & Wei, 2014, 2016).

Regularization of distributional preferences

It is not entirely unexpected that the masculine determiner is assigned by default in these circumstances considering that this gender has been interpreted as being unmarked in Spanish (Harris, 1991). This proposal likely accounts for why the P600 effect in non-codeswitchers was found in conditions involving feminine nouns, but not in conditions involving masculine nouns. One possibility regarding the mixed NP asymmetry is that codeswitchers displayed a weakening of the grammatical gender representation of Spanish nouns in production given their extensive immersion experience living in a predominately English speaking environment (e.g., Schmitt, 2010). However, participants' Spanish unilingual utterances in the codeswitching map task demonstrate that participants can correctly specify grammatical gender; therefore, these data speak against this interpretation. Although our understanding of the asymmetric gender pattern of mixed NPs is still in its early stages (see Valdés Kroff et al. (2016), for a recent consideration of these matters), it may be that some key aspects about the nature of mixed NPs are overlooked when examining production data alone. To illustrate, while our production data provides evidence for a default gender assignment strategy, comprehension processes suggest a more central role of congruency as evidenced in the absence of differences between congruent and incongruent feminine conditions in codeswitchers. Taken together, it may be that the status for masculine determiners in concert with congruency may better elucidate the nature underlying the mixed NP asymmetry.

These interpretations raise the question of whether non-codeswitchers could eventually learn codeswitching regularities given enough linguistic input. In Experiment 3, non-codeswitchers produced codeswitches very rarely, despite being exposed to codeswitches produced by the confederate. Although less frequent structures have been found to be primed more strongly (Ferreira, 2003; Hartsuiker & Westenberg, 2000; Jaeger & Snider, 2008), the quantification of non-codeswitchers' utterances suggest otherwise. Instead, our viewpoint is that any priming that occurred during the production task was limited to language choice, but not to the structural switch points per se.

Future studies should examine the extent to which distributional patterns can be implicitly learned via training. If codeswitching regularities are more about distributional community preferences than about grammaticality, then the effect of training would manifest itself in the form of the N400 as we have seen in the experienced codeswitchers. Alternatively, if training is associated with increases in proficiency (Morgan-Short, Sanz, Ullman, & Steinhauer, 2010), the effect would show up as a P600 effect that results from acquiring sensitivity to gender agreement violations. Codeswitching provides a unique opportunity to examine regularities that emerge in naturalistic production because, unlike monolingual speech, the distributional probabilities in codeswitched utterances can unambiguously reflect differences in syntactic probabilities rather than differences in meaning. To illustrate, whether a codeswitch occurs at the English determiner 'the' (e.g., '<u>Ana vio</u> the dog', "Ana$_{SPAN}$ saw$_{SPAN}$ the$_{ENG}$ dog$_{ENG}$") or after the Spanish determiner '<u>el</u>' (e.g., '<u>Ana vio el</u> dog', "Ana$_{SPAN}$ saw$_{SPAN}$ the$_{SPAN}$ dog$_{ENG}$"), the meaning of the utterance does not change. Because the two variants do not differ in meaning, predicting the presence of an English word after 'the$_{ENG}$' or '<u>el</u>$_{SPAN}$' can be more readily attributed to the syntax of codeswitched speech. In this way, using codeswitching as a research tool to identify the production choices speakers make is an innovative way to pursue the dynamic nature of bilingual language processing and to extend language science. Furthermore, although an individual's linguistic behavior is best understood through the study of speech communities and social networks (Labov, 2010; Sankoff, 1988; Torres Cacoullos & Travis, 2015), we believe that the codeswitching map task is one step in that direction and makes for a more sensitive measure than self-reports of codeswitching and domains of language use.

We note that previous studies have used confederate-scripted techniques to induce codeswitching in an experimentally controlled setting. Kootstra, van Hell, and Dijkstra (2010), for example, tested the extent to which codeswitching behavior is influenced by an interlocutor in dialogue. In their study, dyads of Dutch-English bilinguals took turns describing pictures to each other. Codeswitching was induced by an external cue, but participants were free to decide at what position in the sentence they would switch. The picture descriptions of the confederate were manipulated to codeswitch at prescripted syntactic positions in order to test the extent participants would align their codeswitching patterns with those of their partner. The results showed that the participants' switch positions were influenced by the confederate's codeswitching patterns. Given this finding, one question is why the linguistic behavior of non-codeswitchers does not reflect the confederate's use of mixed NPs. While the codeswitching map task was not setup to specifically test for alignment between conversational partners, one reason for this might be that the bilinguals in our task were not externally cued to codeswitch. Because the codeswitching that took place during the task was strictly voluntary, it is not surprising that non-codeswitchers chose to switch languages less often than codeswitchers. This distinction is important because it has been observed that speakers' tendency to codeswitch is primed more by their own speech than by their interlocutors's speech (Fricke & Kootstra, 2016). We also note that our a priori expectations regarding the differences between the codeswitching behaviors of the two groups were based on previous documentation of the participants' interactional contexts. Future work should test the differential effects of self-priming vs. interlocutor-priming in codeswitching, and the extent to which these factors interact with the behavioral ecology of bilingual speakers.

The coordination of language resources

In the electrophysiological literature, surprisal or reanalysis effects are commonly observed in the processing of mixed language (Moreno et al., 2002; Ng et al., 2014). However, the current study differs from prior studies in considering the effects of the gender production asymmetry on the processing of mixed NPs. We argue that an alternative explanation for previously-observed surprisal effects pertains to the codeswitches themselves. That is, while codeswitches in general should be unexpected for non-codeswitchers, only rarely-attested switches should induce processing difficulties in codeswitchers. Consistent with the latter prediction, non-codeswitchers did not exhibit sensitivity to the mixed NP asymmetry. Notwithstanding, non-codeswitchers did show a switch effect in the form of an early frontal positivity.[4] Because no language effects were found in Experiment 2, where English and Spanish unilingual sentences were presented separately, the modulation of this early processing component must have occurred as a consequence of detection of an unexpected switch (e.g., Kuipers & Thierry, 2010). Importantly, codeswitchers did not exhibit such switch costs. While this may be due to codeswitchers' higher exposure to English, L2 proficiency alone cannot sufficiently explain why switch patterns of the sort found in naturalistic corpora resulted in more efficient processing.

We propose that the modulation of this early frontal positivity bears out the predictions of the control processes model (CP model; Green & Wei, 2014, 2016), which posits that different contexts of language use differentially mediate the dynamics of language control in bilingual speakers. The CP model proposes that while bilinguals in unilingual (single-language) and bilingual (dual-language) contexts typically experience a *competitive* relationship between their languages that is created by the need to actively select one language over the other, bilinguals in dense-codeswitching contexts experience a *cooperative* relationship for managing the demands of production and comprehension processes. More specifically, the CP model assumes that control states

[4] One of the reviewers suggested that this effect could be a reflection of a P2-N2 modulation. As pointed out in Luck (2014), the P2 wave is often difficult to distinguish from overlapping N2 and P3 waves. For the purpose of this study, we follow the interpretation proposed by Berti (2016), in which the frontal positivity in the 230–330 ms time window includes a mixture of a P2-like component and the P3a.

will differ with respect to the coordination of language resources: while a competitive control state exploits the resources of a single language and requires a *narrow* focus of attention, a cooperative control state involves a *broad* focus of attention based on whether resources are recruited from one language or both. The CP model specifically predicts that differences in speakers' interactional behaviors (e.g., codeswitching) are associated with distinct control states. Our interpretation of this modulation across codeswitching and non-codeswitching bilinguals is that it reflects differences between competitive and cooperative control states, as proposed in the CP model. Because the modulation of this early positive component has been proposed to index mechanisms related to attentional control (Berti, 2016; Luck & Hillyard, 1994), codeswitches might trigger an attentional shift from a narrow to a broad attentional state in bilinguals who routinely engage in a competitive control state. Because codeswitchers are in a context in which the regular use of both languages is expected, language regulation and control processes can opportunistically adapt to a switch in language so long as they conform to community norms. While unexpected codeswitches triggered a differential processing strategy, these differences were reflected at later stages of lexical integration. Overall, what these results suggest is that both groups demonstrated differential sensitivity to codeswitched stimuli that mirrors their expectations given their previous language experience.

Conclusion

The current study provides a novel source of evidence that individuals are highly sensitive to the constraints of their language experience, and sheds light on how production and comprehension processes are tightly linked. Particularly regarding codeswitching, our findings demonstrate how switching costs largely depend on the type of codeswitch and bilinguals' language experience. This is an important new finding that might have been overlooked had we not examined bilingual speakers who differed in their exposure to particular distributional regularities. We capitalize on the importance on assessing codeswitching experience in bilingualism research and encourage future research to adopt a comparative approach of combining behavioral (production) and ERPs (comprehension) of the same bilinguals in the study of codeswitching. Taken together, our work illustrates the importance of considering adaptive changes as a function language experience in the study of language processes.

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A. Supplementary material

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.jml.2017.04.002.

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