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Examining the relationship between comprehension and production processes in code-switched language

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ABSTRACT

We employ code-switching (the alternation of two languages in bilingual communication) to test the hypothesis, derived from experience-based models of processing (e.g., Boland, Tanenhaus, Carlson, & Garnsey, 1989; Gennari & MacDonald, 2009), that bilinguals are sensitive to the combinatorial distributional patterns derived from production and that they use this information to guide processing during the comprehension of code-switched sentences. An analysis of spontaneous bilingual speech confirmed the existence of production asymmetries involving two auxiliary + participle phrases in Spanish–English code-switches. A subsequent eye-tracking study with two groups of bilingual code-switchers examined the consequences of the differences in distributional patterns found in the corpus study for comprehension. Participants' comprehension costs mirrored the production patterns found in the corpus study. Findings are discussed in terms of the constraints that may be responsible for the distributional patterns in code-switching production and are situated within recent proposals of the links between production and comprehension.

Introduction

A hallmark of proficiency in two languages is code-switching (the alternating use of two languages in bilingual speech). Proficient bilinguals often code-switch in the midst of speaking with or writing to other bilinguals. The following email illustrates the point clearly (code-switched material appears in bold and capital letters for ease of presentation; translation appears in square brackets).

> On Mon, 9 Jul 2007 17:50:33-0400 (sender's name omitted) wrote:
> Tuesdays at 6:30 pm **SUENA BIEN**. If there's enough people interested in playing, maybe **PODEMOS EMPEZAR** tomorrow **MARTES**. **¿QUÉ PIENSAN?** We could play in the IM building. The place **TIENE** three volleyball courts **QUE ESTÁN** available most of the time. **COMO DIRÍAN LOS** commentators of the Puerto Rican Volleyball Federation...
>
> [Tuesdays at 6:30 pm **SOUNDS GOOD**. If there's enough people interested in playing, maybe **(WE) CAN START** tomorrow **TUESDAY. WHAT DO (YOU) THINK?** We could play in the IM building. The place **HAS** three volleyball courts **THAT ARE** available most of the time. **AS THE** commentators of the Puerto Rican Volleyball Federation **WOULD SAY**...

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For several decades, code-switching was regarded as random interference of one language with the other (e.g., Lance, 1975). We now know that code-switching is rule-governed (e.g., Deuchar, Muysken, & Wang, 2007; MacSwan, 2000; Myers-Scotton, 2002; Toribio, 2001), although there is little agreement on the precise nature of the rules involved. There is consensus, however, as to the observation that code-switching is a remarkable feat of bilingual communication that gives language scientists the potential to understand how humans negotiate the boundaries of two languages (e.g., Kroll, Dussias, Bice, & Perrotti, 2015; Kroll, Dussias, Bogulski, & Valdés Kroff, 2012).

Code-switching presents a unique cognitive puzzle on the link between production and comprehension. In particular, the production of code-switched speech is putatively under the control of bilingual speakers, as evidenced by their ability to speak in one language when necessary (e.g., when speaking to a monolingual conversational partner). Yet bilingual comprehenders do not *a priori* know when a code-switch will occur in speech. In this sense, switches can be unexpected and, thus, potentially more difficult to process than within-language sentences. In support of this, several studies on the comprehension of code-switched language have documented costs associated with processing code-switches (e.g., Altarriba, Kroll, Sholl, & Rayner, 1996; Bultena, Dijkstra, & Van Hell, 2015; Proverbio, Leoni, & Zani, 2004). Given the presence of switch costs, it is on the surface surprising that bilinguals rarely report experiencing difficulties comprehending code-switched discourse. In fact, bilinguals often have difficulty remembering which language was used in any particular speech exchange (Gumperz, 1982) and are often not able to unequivocally indicate the precise locus of a recently produced code-switch (Toribio, 2001). These facts suggest the existence of factors that mitigate switch costs. This logic resonates with what has been proposed in many studies of monolingual syntactic ambiguity resolution: the observation that readers garden-path only occasionally, even though temporary ambiguities are common, indicates that they use cues from production to guide their initial choices (e.g., Garnsey, Pearlmutter, Myers, & Lotocky, 1997).

The main goal of the work presented here is to test the hypothesis, derived from experience-based models of processing (represented in the work of, e.g., Boland, Tanenhaus, Carlson, & Garnsey, 1989; Britt, 1994; Gennari & MacDonald, 2009; Holmes, Stowe, & Cupples, 1989; MacDonald, Pearlmutter, & Seidenberg, 1994; McRae, Hare, Elman, & Ferretti, 2005; Novick, Thompson-Schill, & Trueswell, 2008; Pickering & Garrod, 2013), that bilinguals are sensitive to the combinatorial distributional patterns derived from production and that they use this information to guide processing during the comprehension of code-switched sentences. As will be shown below, our approach exploits the power of the unique linguistic environment in which bilinguals find themselves to reveal the central influence of production and its relationship to the linguistic representations that speakers recruit during comprehension (e.g., Dell & Chang, 2014; Levy, 2008). A second aim is to add bilingualism to the discussion of how language production affects language comprehension with the purpose of broadening the evidential base. The evidence in favor of experience-based models of processing has largely come from studies with monolingual speakers, and predominantly from studies on syntactic ambiguity resolution or the interpretation of subject/object relative clauses. Given the demographic reality that more speakers around the world are bilingual, bilingualism can and should be used as a tool to uncover important aspects of language function that may be obscured or difficult to study when examining the behavior of individuals who speak only one language (see Kroll, Bobb, & Hoshino, 2014). In the work reported here, we use the presence of code-switching in bilingual communities to test the correspondence between production patterns and comprehension difficulty proposed in experience-based models of language processing.

Switch costs

An important distinction in the code-switching literature is the division between inter-sentential and intra-sentential switches. Inter-sentential code-switches take place at sentence boundaries, as in example 1, and intra-sentential switches occur within sentence boundaries, as in example 2 (in both examples, Spanish words appear in italics; the underlined portion comprises the switch).

(1)	I need to go to the pharmacy.	<u>*Tengo que comprar aspirina.*</u> '...(I) have to buy aspirin.'
(2)	*Mi tía dijo que* <u>my uncle left.</u> 'My aunt said that...'	

Intra-sentential switches require greater simultaneous control of both languages, creating a unique opportunity to observe the interaction between two linguistic systems. Languages across the world differ in their statistical regularities even when surface structure is similar (e.g., Dussias, Marful, Gerfen, & Bajo Molina, 2010). An open question, then, is how bilingual speakers successfully navigate between two languages within the same sentence. Do bilinguals follow the specific distributional statistics of one language or the other when engaged in code-switching? Or do they develop knowledge of when code-switches are more likely to occur? If the interaction between linguistic systems and the constraints that guide their successful integration during code-switching can be systematically characterized, we propose that they provide a valuable means of investigating questions concerning the relationship between sentence production and comprehension.

Quantitative studies on intra-sentential switching involving a number of language pairs have revealed that certain types of syntactic junctures are more likely to serve as the loci of code-switching than others. If exposure-based models generalize to code-switched speech, then bilinguals presumably use this distributional information to guide their predictions of where code-switches are more likely in comprehension. Yet most of the evidence involving switches between languages points to the existence of processing costs relative to staying within the same language. One source of evidence for switch costs has been reported in studies of language switching during lexical decision tasks. Findings from such studies (e.g., Grainger & Beauvillain, 1988; Grainger & O'Regan, 1992; Thomas & Allport, 2000; von Studnitz & Green, 1997) demonstrate that recognizing and integrating a linguistic code distinct from the code most recently encountered incurs a processing cost for the comprehender. However, the implications of these results for understanding the effect of real-world code-switched language are limited by the fact that the vast majority of these studies employ decontextualized language switching tasks involving words presented in isolation and where the target language is determined by the experimenter (but see Gollan & Ferreira, 2009), while actual code-switching in bilingual communication is an inherently discourse-based phenomenon, where the two languages of the bilingual are fully engaged, and where code-switching is entirely under the control of the speaker. Given this, the switching cost triggered by a language change in the lexical switch studies cited above might well be viewed as analogous to switch costs incurred in non-linguistic domains (e.g., Allport, Styles, & Hsieh, 1994) and not as a clear indication that code-switching in natural discourse will necessarily incur costs in the same manner (see also Myslín & Levy, 2015).

Few, but important, studies have examined the consequences of sentence-level switching for comprehension and have returned a mixed set of results. Some studies have revealed that processing intra-sentential code-switches is costly. For example, in an eye-tracking reading study, Altarriba et al. (1996) demonstrated that noun switches were fixated longer than synonymous within-language words; similarly, using event-related potentials, Proverbio et al. (2004) showed longer reaction times and increased N400 amplitudes for processing code-switched words. However, other studies provide evidence that switch costs can be mitigated. For example, Moreno, Federmeier, and Kutas (2002) found that the enhanced late positivity that they observed for code-switched words was reduced when the switch was less unexpected. Chan, Chau, and Hoosain (1983) provided evidence that reading times for long stretches of mixed-language passages were the same as those for equivalent unilingual passages, suggesting that discourse-level context also facilitates the processing of code-switching. In the auditory domain, studies have also investigated how bilinguals comprehend a word when it is spoken in a language (the "non-target" or "embedded" language) that is different from the language of the preceding sentence context (e.g., Grosjean, 1988; Li, 1996; Soares & Grosjean, 1984). The results indicate that the extent of activation of the non-target alternative is modulated by phonetic cues available to the listener, such as the phonotactic structure of the code-switched target item. From these findings, it is clear that although one can isolate costs associated with code-switching, researchers have also identified conditions under which the comprehension of code-switched target items is facilitated.

In the work presented here, we test the hypothesis that bilingual comprehenders exploit potential cues rooted in their linguistic experience with code-switched constructions to facilitate the comprehension of upcoming other-language items. Cues can be present at multiple linguistic levels. For example, they exist as subtle low-level cues, such as slight changes in VOT before a code-switch (e.g., Balukas & Koops, 2015; Fricke, Kroll, & Dussias, 2016) and slow speech rate (Fricke et al., 2016); they may also be discourse-driven such that certain topics are more likely than others to elicit code-switches (e.g., Myers-Scotton, 1993). In addition, code-switches may be used as a strategy among bilinguals to more saliently encode for meanings of low predictability and high information content (Myslín & Levy, 2015). Here we examine whether experience with patterns of code-switching in production prepares the comprehender for the relative likelihood of encountering a code-switch in a given context. Our hypothesis is that bilinguals who are exposed to code-switching are able to extract patterns of likely code-switches from the exemplars of bilingual utterances in their community; these patterns, in turn, become reliable indicators of when code-switches are more likely to occur in the speech of their interlocutors. If bilinguals can successfully tap into knowledge about statistical regularities in the production of code-switched speech, then they should be able to exploit this knowledge to facilitate the comprehension of code-switched language, which should reduce or eliminate switch costs. Findings such as these would suggest sensitivity to production statistics in comprehension and would be congenial with proposals highlighting that exposure-based factors guide readers' comprehension (Bybee, 2013; Goldberg, 2006; Langacker, 1987; MacDonald, 1999, 2013; MacDonald & Seidenberg, 2006).

Production asymmetries in code-switched speech

We capitalize on the presence of production asymmetries in code-switched discourse to examine the relationship between production and comprehension. Of particular relevance for our purposes, several studies examining the production of Spanish–English intra-sentential code-switches (e.g., Lipski, 1978; Pfaff, 1979; Poplack, 1980) have documented an asymmetry involving alternations within the auxiliary phrase—the structure under investigation in the current study. Specifically, code-switching into an English participle preceded by the Spanish auxiliary *estar* 'be' (e.g., *los niños* <u>*están* cleaning</u> their rooms 'the children are ...') occurs as frequently in corpora as code-switches in which both the auxiliary and the participle appear in English (e.g., *los niños* <u>are cleaning</u> their rooms). However, code-switches into an English participle preceded by the Spanish perfect auxiliary *haber* 'have' (e.g., *los niños* <u>*han* cleaned</u> their rooms 'the children have...') are considerably less frequent than code-switches in which both the auxiliary and the participle appear in English (e.g., *los niños* <u>have cleaned</u> their rooms). The preponderance of switches involving progressive structures over perfect structures illustrates the differential behavior of these two switches in bilingual production. Importantly, the differences in distributional probabilities of these code-switches reflect differences in syntactic probabilities and not differences in meaning biases. That is, although the progressive and perfect forms inherently convey different temporal meanings, whether a code-switch is produced at the verb phrase boundary (i.e., at the auxiliary) or at the participle (i.e., immediately following the auxiliary) does not change the meaning of the utterance. In other words, '*los niños* are cleaning their rooms' means exactly the same thing as '*los niños* *están* cleaning their rooms' and '*los niños* have cleaned their rooms' means the same as '*los niños* *han* cleaned their rooms.' This is an important point when examining the predictions of models arguing that frequency of exposure to certain constructions is a major factor guiding sentence comprehension (e.g., Jurafsky, 1996; MacDonald & Seidenberg, 2006). Because the two variants (e.g., 'are cleaning' and '*están* cleaning') do not differ in meaning, findings that show frequency effects in comprehension can be more readily attributed to particular distributional patterns in code-switched speech than to the meaning conveyed by the structures themselves.

We will address possible reasons for the distributional patterns in production of these two types of code-switches in the next section, but the critical point here is that these code-switches have been reported in a variety of corpus studies to occur with different frequency. As mentioned earlier, growing evidence from experience-based studies of sentence processing indicates that frequency of exposure to certain word combinations modulates comprehension difficulty. Whether such correspondences between comprehension and production extend to code-switching is an empirical question, but the results from monolingual research lead us to predict that the differential probability of producing a code-switch at a participle when it is preceded by the auxiliary *estar* and by the auxiliary *haber* will result in different behaviors when bilinguals comprehend these two types of code-switched structures. Participants are predicted to process switches at the auxiliary and those at the participle involving the progressive structure similarly. However, when the perfect structure is involved, switches at the auxiliary should incur less processing disruptions relative to switches at the participle.

Why production patterns look the way they do

One proposal that captures production asymmetries in code-switching is the 4-M model (Myers-Scotton, 1993; Myers-Scotton & Jake, 2001). The model takes as a starting point the observation of a general constraint on the "switchability" of closed-class items (e.g., determiners, some prepositions, complementizers, etc.). From a psycholinguistic perspective, this observation is of interest because the differential behavior of closed-class words relative to open-class words has been noted in various aspects of monolingual production: (a) certain types of speech errors strand closed-class items; (b) closed-class categories resist loss and incorporation of new words; (c) in lexical decision, closed-class, but not open-class, items show frequency-independent behavior; (d) work on aphasia has shown that open- and closed-class items are differentially affected (e.g., Bradley, Garrett, & Zurif, 1979; Joshi, 1985). Although it is generally uncontroversial that closed-class words resist code-switching, researchers have noted some puzzling exceptions. To illustrate, whereas some prepositions resist switching (e.g., the object-marker preposition *a* 'to' in Spanish), others switch freely (e.g., prepositions that assign theta roles, such as Spanish *con* 'with'). The 4-M model portrays the differential participation of closed-class items in code-switching, and the concomitant production asymmetries, by classifying closed-class items in terms of their empirically-evident syntactic roles and of hypotheses regarding how and when they are retrieved in language production. The basic insight is that not all closed-class items are equal. So-called "early system morphemes" (e.g., theta-role assigning prepositions, determiners, some auxiliaries) are salient at the level of the conceptualizer (in terms of Levelt's 1989 speech production model) and, thus, free to participate in code-switching. Conversely, "late system morphemes" (e.g., case affixes in some languages, morphemes marking subject or object agreement, some auxiliaries, case marking prepositions) are structurally assigned and, hence, not salient until later during language production (where grammatical encoding takes place). Because of this, they do not easily participate in code-switching.

With respect to the structures examined in this study, the model inherently predicts code-switching asymmetries in production, given that the auxiliary *estar*, an early system morpheme, is retrieved at a different stage during sentence planning than *haber*, a late system morpheme. By locating late system morphemes in the syntactic frame, the proposal links their retrieval to syntactic processing, in contrast to content and early selection morphemes, which are more dependent on semantic information and are retrieved earlier. If this analysis is correct, *estar* should be salient at the level of the mental lexicon, and switches involving the *estar* + English participle structure should have no particular restrictions on their production. Conversely, because *haber* functions as a placeholder in Spanish (i.e., it is void of meaning) for the expression of grammatical features, the well-formedness requirements of Spanish oblige *haber* to appear in participial structures; therefore, the entire *haber* + participle phrase is salient at a later stage in the retrieval process, when late system morphemes are structurally-assigned in the syntactic frame. This later retrieval, then, restricts code-switches between *haber* and an English participle (We return to the 4-M model in the 'General discussion' section).

The paper is structured as follows. In the next section, we report the findings of a corpus study conducted to confirm the differences reported in past code-switching literature regarding the production asymmetries discussed above. Then, we present the results of an eye-tracking experiment that examined the consequences of the differences in distributional patterns found in the corpus study for the comprehension of code-switched sentences. We investigate this question with two groups of Spanish–English bilinguals: one group exposed to code-switched speech early in life and another group exposed to code-switching later in life (during late adolescence or adulthood). We predicted the following. If frequently produced code-switch types are processed with more ease than less frequent ones, then *haber* + English participle switches (e.g., *los niños* han cleaned 'the children have...') should produce longer reading times than their corresponding phrasal boundary switches (e.g., *los niños* have cleaned). However, there should not be reading time differences between *estar* + English participle switches (e.g., *los niños* *están* cleaning 'the children are...') and their corresponding phrasal boundary switches (e.g., *los niños* are cleaning) because both types of code-switches are found in spoken and written corpora with approximately the same frequency of occurrence. In addition, if the amount of previous exposure to and use of code-switching influences comprehension costs of code-switched sentences, then the early exposure group and the late exposure group should display different reading times at the code-switched region under examination. Specifically, because of their increased experience with the second language and, potentially, with code-switching, the early exposure group's fixation durations should better reflect the code-switching patterns found in naturalistic production corpora, when compared to those of the late exposure group. We end with a general discussion of our results.

Corpus study

Code-switching may or may not be a community discourse mode (Poplack, 1980). When it is, it is produced alongside copious stretches of unilingual discourse. This means that there are no code-switching corpora per se; instead bilinguals speak to other bilinguals using stretches of discourse in one of their two languages, with single-word or multi-word code-switches interspersed. A good example of this is the Bangor Miami Corpus of English–Spanish Codeswitching (Deuchar, Davies, Herring, Parafita Couto, & Carter, 2014). The corpus is made up of approximately 43,327 utterances collected during 35 h of bilingual speech. Of these, 26,801 utterances are unilingual English, 13,999 are unilingual Spanish, and 2527 are code-switched. Major categories, such as single nouns, together with subject noun phrases, object noun phrases, and subordinate clauses most often participate in intra-sentential code-switching, leaving a relatively small opportunity to observe code-switches at other syntactic sites, including switches at the auxiliary phrase. As a way of illustration, 510 (60%) of the intra-sentential code-switches reported by Poplack (1980) involved major constituents, whereas only 59 switches (6.9%) involving the auxiliary phrase were observed. This does not mean that generalizations extracted from a small number of code-switches are not valid. The "Equivalence Constraint" (Poplack, 1980), arguably one of the constraints on grammatical code-switching that has stood the test of time, was based on only 851 intra-sentential code-switched utterances gathered during 66 h of bilingual recordings. What it means, though, is that generalizations derived from one code-switching corpus need to be supported through the examination of other corpora. The corpus study presented below, therefore, was carried out to corroborate the production patterns described in earlier work.

We examined available oral and written Spanish–English code-switching corpora to confirm the distributional patterns involving switches at the two syntactic sites under investigation here: Spanish *estar* + English participle and Spanish *haber* + English participle. The oral corpus examined was the Bangor Miami corpus (Deuchar et al., 2014); the corpus consists of recordings of informal conversations between pairs of Spanish–English bilingual speakers living in Miami, Florida (collected in 2008).[1] Twenty-six transcriptions (approximately 390,000 words) that are available on Talkbank (http://talkbank.org/browser/index.php?url= BilingBank/Bangor/Miami/) were examined. The written corpus was extracted from a weekly editorial column entitled *La Calentita: Gibraltar's National Dish*, which is included in the online version of the Gibraltar newspaper, *Panorama* (http://www.panorama.gi). This newspaper column is written in informal language, it mimics a conversation between two women who review the country's current events, and it includes numerous instances of Spanish–English code-switching, matching the popular and frequent use of code-switching amongst locals, which they refer to as *llanito* (Moyer, 1995). Eighty-eight editorial column entries that appeared between 2004 and 2011 (approximately 25,300 words) were examined. Despite obvious differences between written and spoken language, the data extracted from the Miami and the Gibraltar corpora displayed similar switching patterns. Moreover, in her comparison of oral and written Gibraltarian code-switches, Moyer (1995) reported patterns of code-switches that were similar to those described by Lipski (1985), Pfaff (1979), and Poplack (1980) for U.S. bilingual communities. Importantly, our corpus analysis confirmed a claim made in past code-switching literature: during code-switched speech, switches at the auxiliary and at the participle occur with similar frequency when the verbal bundle comprises the progressive structure, but when it involves the perfect structure, switches at the former site are much more frequent than those at the latter site.

Extraction and coding procedure

For the analysis, we searched the transcriptions and the editorial column entries for instances of the progressive structure (i.e., the Spanish auxiliary *estar* and the English auxiliary *be* in its full or contracted form followed by a present participle) and the perfect structure (i.e., the Spanish auxiliary *haber* and the English auxiliary *have* in its full or contracted form followed by a past participle). In the written corpus, sentence boundaries were divided by periods. In the oral corpus, instances in which the transcriptions lacked punctuation that clearly demarcated the beginning and end of sentences were treated following a conventional procedure in sociolinguistic research whereby the entire conversational turn of a participant is

[1] A detailed description of the corpus, recruitment methods, data collection, and data transcription can be found in Deuchar et al. (2014).

defined as a sentence. All grammatical subjects for the progressive and perfect structures were included in the analysis (e.g., noun phrases and pronouns, all grammatical persons, animate and inanimate subjects, individual and collective subjects), as well as all types of sentences (e.g., declarative and interrogative, affirmative and negative). Finally, the progressive and perfect structures were included with auxiliary forms in the present, past, and future tenses and the indicative and subjunctive moods.

After the initial extraction from both corpora, the following four criteria were applied to the sample. Tokens of the progressive structure were excluded if they referred to a future action (e.g., "I'm leaving on Friday"). The use of the progressive structure to signal future only exists in English; in Spanish the future is expressed with simple future or periphrastic future constructions. Because this particular use of the progressive structure could be considered an environment in which a code-switch might be blocked due to lack of equivalence across languages, all instances were excluded. In the case of the oral corpus, tokens were also eliminated if the auxiliary was not pronounced and, therefore, not spelled out in the transcriptions (e.g., "...because they offering him a big salary"). In addition, tokens were excluded when they contained the perfect structure with the past participle of the verb *get* because these phrases carried a possession meaning instead of a past action meaning (e.g., "and then he's got this black and blue bruise"). Finally, tokens that comprised idioms or fixed phrases with either the progressive or the perfect structure (e.g., "You are telling me, Cynthia *de mi corazón*" '...of my heart') were eliminated from further analysis. In all, 36 tokens were excluded from the analysis, representing less than 3% of the data. From the remaining tokens, we selected only those that contained a code-switch somewhere in the sentence—in other words, sentences that included both Spanish and English words. These code-switched sentences constituted the code-switched corpus for the analysis. For each sentence or conversational turn, code-switches with the progressive or perfect structure were coded for whether they occurred immediately before or immediately after the auxiliary phrase, at the auxiliary, at the participle, or elsewhere in the sentence.

Results

After applying the criteria for exclusion, 845 sentences with the progressive structure and 375 sentences with the perfect structure were extracted from the Miami oral corpus. An additional 142 sentences with the progressive structure and 183 sentences with the perfect structure were extracted from the Gibraltar written corpus. Because the main goal of the corpus study was to verify the distributional patterns of code-switches reported in past code-switching studies (e.g., Pfaff, 1979) involving the two structures, the data analyzed included only the subset of sentences in which a code-switch was instantiated from Spanish to English. In the following section, processing difficulty is assessed on switches going in this direction only. Table 1 displays the distribution of code-switches by syntactic position.

As shown in Table 1, there were numerically more code-switches involving the progressive and perfect structures in the written corpus (106 and 150, respectively) than in the oral corpus (93 and 28, respectively). In the written corpus, the code-switched tokens represented approximately 79% of the total number of the extracted sentences, while in the oral corpus they constituted a little less than 10% of the data. This difference is not surprising given that the editorial column from Gibraltar was written with frequent code-switching by design; in contrast, the oral corpus is a collection of conversations that took place between bilingual speakers. In compiling the corpus, the researchers simply asked the bilingual participants to speak as they normally would, without explicit reference to code-switching (see Deuchar et al., 2014). Whereas the number of code-switches involving the progressive structure was similar between the two types of corpora (93 tokens in the oral corpus and 106 in the written corpus), there were more code-switches involving the perfect structure in the written corpus (150 tokens) than in the oral corpus (28 tokens), likely reflecting the topics discussed in each type of corpus. These differences aside, the oral and written corpora show remarkable overlap with respect to the distribution of the switch locations examined here. When the progressive structure was involved, switches were just as likely to occur at the participle (e.g., *los niños están* cleaning... 'the children are...') as switches at the auxiliary (e.g., *los niños* are cleaning...).

In the oral corpus, seven sentences included a switch at the progressive auxiliary and another seven included a switch at the present participle, each of these representing 7.53% of the code-switched data. Therefore, a switch was as likely to occur at the auxiliary as it was to occur at the present participle. However, turning to sentences with the perfect structure, three (10.71%) included a switch at

Table 1
Distribution of code-switches by syntactic site (Spanish to English switches).

	Oral corpus (Miami)				Written corpus (Gibraltar)			
	Progressive		Perfect		Progressive		Perfect	
	Tokens	%	Tokens	%	Tokens	%	Tokens	%
Switch immediately preceding auxiliary	3	3.22	0	–	1	0.94	1	.667
Switch at auxiliary	7	7.53	3	10.71	8	7.55	14	9.33
Switch at participle	7	7.53	0	–	8	7.55	1	.667
Switch immediately following participle	13	13.98	6	21.43	9	8.49	28	18.67
Switch elsewhere	63	67.74	19	67.86	80	75.47	106	70.67
Total	93	100	28	100	106	100	150	100

the perfect auxiliary and none included a switch at the past participle. In the written corpus, a very similar picture emerges. In this case, eight sentences included a switch at the *estar* auxiliary and an additional eight sentences included a switch at the present participle, each of these representing 7.55% of the code-switched data. Thus, the results of the written corpus confirm that a switch at the *estar* auxiliary and a switch at the present participle are equally probable. These percentages of occurrence are strikingly similar across the two corpora. Regarding the sentences that included the perfect structure, in 15 of them, the switch occurred at the *haber* auxiliary, representing 10% of the code-switched data, and there was one occurrence of a switch at the past participle. Once again, these results closely resemble those in the oral corpus.

It is also worth noting that the particular examples of switches at the present participle are similar across both corpora. In oral and written form, there are cases in which the *estar* auxiliary and the English present participle are adjacent to each other and other cases in which there is intervening linguistic material. In addition, in both corpora the code-switched progressive structure appears with varied grammatical subjects (i.e., noun phrases, pronouns, omitted subjects) and the *estar* auxiliary appears in different tenses (i.e., present, past).

In order to confirm these numerical trends, we conducted Fisher's exact tests (due to our small sample sizes) on the production distributions for each auxiliary + participle form to test whether the distributions were significantly different from each other across the oral and written corpora. For both the progressive and perfect structures, there were no significant differences in production distributions across the two corpora (progressive structure, $p = .55$; perfect structure, $p = .89$). Consequently, we combined the tokens from the oral and written corpora for the code-switches at the auxiliary (e.g., *los niños* <u>are cleaning</u>...) and those at the participle (e.g., *los niños* <u>*están* cleaning</u>...). To test whether present or perfect structure code-switches are equally likely to be produced at the auxiliary or at the participle, we performed binomial tests on the success of producing code-switches at the auxiliary (out of tokens comprising code-switches at the auxiliary and at the participle) at more than 50% probability. The production of code-switches at the auxiliary involving the progressive structure is not significantly greater than 50% (15/30, $p = .57$). In contrast, the production of code-switches at the auxiliary involving the perfect structure is significantly greater than 50% (17/18, $p < .001$).

These results reveal that *estar* + participle switches are more frequently found in natural oral and written production corpora than *haber* + participle switches. According to these data, Spanish–English bilinguals seem to be equally likely to switch at the auxiliary or at the present participle when using the progressive structure. However, when using the perfect form, they avoid switching at the past participle. Instead, they switch at the auxiliary or right after the past participle. In all, our findings confirm the asymmetric distribution of *estar* + participle switches and *haber* + participle switches reported in past studies (Lipski, 1978, 1985; Pfaff, 1979; Poplack, 1980).

Eye-tracking study

Taking into consideration the differences in distributional patterns found in our corpus study for the two types of switches examined here, we conducted an eye-tracking study to investigate the consequences of these differences for the comprehension of code-switched sentences. The specific purpose of the eye-tracking study was to examine if the type of code-switch that is more frequently found in naturalistic production (i.e., a switch at the participle involving the progressive structure) is processed with more ease than the type of code-switch that is rarely found in code-switching corpora (i.e., a switch at the participle involving the perfect structure).

Methods

Participants

Two groups of Spanish–English bilinguals were recruited. One group (early exposure group, $n = 42$) had acquired Spanish and English in early childhood and had been exposed to Spanish–English code-switching since childhood by virtue of being born, being raised, and living in an established Spanish–English code-switching community in Harlem, New York (NY; see Poplack, 1980). The second group of participants (late exposure group, $n = 27$) was comprised by speakers from Hispanic countries who had immigrated to the United States (US) later in life (mean age of arrival = 18). The majority ($n = 17$) of the participants in the late exposure group were living in the same code-switching community in Harlem. Additionally, we included ten participants in this group who did not live in Harlem, but whose linguistic profile and experience with code-switching were similar to the NY late exposure group (self-reported ratings and proficiency measures, all *ps* > .307). Although they had been living in the US for less time, the participants in the second group had been exposed to Spanish–English code-switching from the moment of arrival in the US. Exposure-based accounts of language processing (e.g., MacDonald & Seidenberg, 2006) suggest that less experience with particular linguistic structures will result in less sensitivity to the distributional patterns of these structures during comprehension. However, the amount of previous exposure that is required to exhibit this sensitivity during comprehension has not yet been addressed. The purpose of including this late exposure group, then, was to ascertain the extent to which amount of time spent living in an established code-switching community (and potentially exposed to Spanish–English code-switching) affected speakers' sensitivity to distributional differences in code-switching production. In other words, we wanted to see if the results obtained with the group of participants who had been exposed to code-switching for all or most of their lives could be replicated with a group of participants who had been exposed to code-switching in the same community for less time.

All participants were undergraduate or graduate students from the City College of New York or from Penn State University. Despite differences in their amount of exposure to code-switching, all participants reported frequently engaging in Spanish–English code-switching with other bilinguals in their adult lives, both in the spoken and the written (emails, instant messages, text messages, chats) modalities. The excerpt included in the 'Introduction' section was taken from an email written by a bilingual participant from this study. It serves to illustrate that code-switching is present, not only in their oral exchanges, but also in these bilinguals' written interactions and, thus, in their reading experience. The participants in both groups completed a series of measures of language proficiency, described below.

Language History Questionnaire. In an online Language History Questionnaire (LHQ), participants provided self-ratings of their English and Spanish proficiency across reading and writing production as well as speaking and listening comprehension. They used a scale in which 1 corresponded to "very low" and 10 corresponded to "perfect." They also answered open-ended and multiple-choice questions about their history with both languages, their language acquisition experiences, and their daily exposure to and use of both languages. Several examples of the questions asked in the LHQ are displayed in Fig. 1.

Boston Naming Vocabulary Test. As a measure of lexical access, vocabulary size, and naming performance, participants completed the Boston Naming Vocabulary Test (BNT; Kaplan, Goodglass, & Weintraub, 1983) in English and Spanish. The BNT contains 60 outline drawings of objects and animals. The images were divided into two language blocks (an English block and a Spanish block) of 30 images each. Participants completed the BNT in their self-reported dominant language first, and then in the other language. In each language block, participants were asked to name the images as quickly and as accurately as possible. The drawings were presented in order of increasing difficulty, starting with easy, high-frequency words, such as *flower* and *cama* ('bed') and concluding with more difficult, low-frequency words like *protractor* and *yunta* ('yoke'). Participants' responses to the BNT were digitally recorded and these recordings were then reviewed to score the test. Participants received a score of 1 for every correctly named image and 0 for every incorrectly named image or for any unnamed image.

Grammar tests. Participants also completed the grammar sections of the Michigan English Language Institute College Entrance Test (MELICET) and the Advanced Test of the Diplomas de Español como Lengua Extranjera (DELE, 'Diplomas of Spanish as a Foreign Language'). The MELICET is an advanced level English language test created by the University of Michigan English Language Institute (http://www.michigan-proficiency-exams.com/melicet.html) to examine ability in different English language areas. It is primarily used to test nonnative speakers of English by educational institutions as an admissions or placement test. The DELE is a standardized test of Spanish issued by the Ministry of Education, Culture, and Sport of Spain, which assesses proficiency in Spanish at seven levels (http://diplomas.cervantes.es/en). The test administered here was the *Nivel Superior C2*, the highest level of accreditation. Each grammar test contained 50 multiple-choice items, which evaluated grammar, vocabulary, and reading competence in isolated sentences, as well as longer stretches of discourse. An example of an item from each

Did you begin to speak both English and Spanish before age 5?

Yes
No

In general, which language do you prefer to use?

English
Spanish
Both
It depends on whom I talk to

Code-switching means using both Spanish and English in the same sentence when you are talking to someone else. Do you ever code-switch?

Yes
No

Why do you think you code-switch?

Fig. 1. Sample questions in LHQ.

test is presented in Table 2. Participants received one point for each correct answer and no points for incorrect answers.

All participants were proficient in English and Spanish and they reported regular use of and exposure to both languages in the oral and written modes. More specific participant characteristics are displayed in Table 3.

Table 3 shows that both groups are very similar in terms of mean age. Within-group comparisons were conducted to explore differences between the participants' proficiency levels in both languages. Results of paired-samples *t* tests for the early exposure participants displayed higher self-ratings and scores for English (self-ratings: $t(41) = 3.62$, $p < .001$; BNT score: $t(41) = 5.38$, $p < .001$; grammar test score: $t(41) = 4.59$, $p < .001$). Conversely, results for the late exposure bilinguals displayed higher self-ratings and scores for Spanish (self-ratings: $t(26) = 5.43$, $p < .001$; BNT score: $t(26) = 5.47$, $p < .001$; grammar test score: $t(26) = 2.15$, $p = .041$). These results demonstrate that the early exposure group was English-dominant while the late exposure group was Spanish-dominant, a finding that is expected given that the former group had been immersed in an English-speaking environment since birth, whereas the latter group had lived in a Spanish-speaking environment and had received schooling in Spanish before coming to the US.

Between-group comparisons were also conducted; the results of several independent-samples *t* tests showed significant differences between both groups for almost all the proficiency measures displayed in Table 3 (self-ratings for English proficiency: $t(67) = 2.33$, $p = .023$; self-ratings for Spanish proficiency: $t(67) = -4.53$, $p < .001$; BNT score for English: $t(67) = 3.27$, $p = .002$; BNT score for Spanish: $t(67) = -7.89$, $p < .001$; DELE score: $t(67) = -6.11$, $p < .001$). The exception was the MELICET score, for which no significant difference between these two groups was found, $t(67) = -0.36$, $p = .719$. Overall, then, the two groups are proficient in both languages, and display differences that are expected given their language histories and language dominance.

Table 2
Sample items in grammatical competency tests.

Sample item from the MELICET	Sample item from the DELE
"What is that thing?" "That _______ a spider." (a) to call (b) for calling (c) be called (d) is called	En la compañía se está decidiendo estos días si _______ nuevos horarios para los trabajadores. (a) haya (b) habrá 'These days the Company is deciding whether _______ new schedules for the workers. (a) there were (b) there will be'

Table 3
Participant characteristics.

Characteristics	Early exposure participants ($n = 42$)	Late exposure participants ($n = 27$)
Age	21 (18–33)	22 (18–32)
Self-ratings for English proficiency (/10)	9.0 (5.75–10)	8.5 (5.75–10)
Self-ratings for Spanish proficiency (/10)	8.3 (5.75–10)	9.4 (7.5–10)
BNT score for English (/30)	20 (9–27)	16 (8–23)
BNT score for Spanish (/30)	14 (7–24)	21 (17–26)
MELICET score (/50)	40 (30–50)	41 (30–47)
DELE score (/50)	35 (20–45)	43 (33–48)

Means are displayed with ranges in parentheses.

Materials and design

The experimental stimuli comprised 48 item sets (see Appendix A) for a total of 192 experimental sentences. Each item set consisted of four different versions of the same sentence, corresponding to the four experimental conditions. Conditions 1 and 2 were code-switched conditions with the progressive structure. In Condition 1, the switch occurred at the phrasal boundary (that is, at the auxiliary) and in Condition 2, it occurred at the participle. Conditions 3 and 4 were analogous to Conditions 1 and 2, but involved the perfect structure instead. In each experimental sentence, the critical code-switched region under examination was part of an embedded phrase to ensure its appearance in the middle of the sentence and, thus, in the middle of the computer screen. Table 4 displays a sample item set (the critical region is underlined).

In addition to the experimental items, 32 filler sentences were added. The fillers were similar to the experimental items in terms of overall length, but differed from them regarding the syntactic structures and the code-switch types included. Three examples of the fillers are provided below.

(3) Switch between the verb and the direct object
Laura estaba limpiando the kitchen before going out with her friends.
'Laura was cleaning...'

(4) Switch between the definite article and the noun
Tomás y su esposa ya habían visto el movie that their friends had recommended.
'Thomas and his wife had already seen the...'

(5) Switch between clauses
Como la maestra ha sospechado, the students have not studied for the exam.
'As the teacher has suspected...'

Five practice items were added at the beginning of the experiment to familiarize participants with the requirements of the task and the type of stimuli.

The experimental sentences were tightly controlled in several ways to ensure that extraneous factors were not responsible for the predicted pattern of results. First, the experimental stimuli were controlled for word length (mean word length 13 [range 11–14]). In addition, the verb of the main clause was always a sentential complement-biased verb or an equi-biased verb, but never a direct object biased verb; this was done to facilitate processing of the following embedded clause. Also, the grammatical subject of the verb in the embedded clause (mean character length 10 [range 5–14]; mean lexical frequency 27.64 [range 1–162][2]) was always a cognate noun in Spanish and English (e.g., *turistas* in the examples in Table 4) in order to maximize cross-linguistic lexical activation. The participle in the critical region (mean character length of the present participles 9 [range 6–11]; mean lexical frequency of the present participles 16.03 [range 1–76]; mean character length of the past participles 8 [range 5–10]; mean lexical frequency of the past participles 51.68 [range 3–401][3]) was from a regular-ending verb in order to keep the spelling of the participles as uniform as possible.

All the sentences were followed by a comprehension question (e.g., for the items in Table 4, it was "Do the tourists seem unsatisfied?"). This was done to guarantee that participants were performing the reading task as expected. Because the sentences always began in Spanish and ended in English, the comprehension questions were presented in English to avoid introducing an inter-sentential code-switch while participants were processing the question. Half of the questions required a "yes" answer and the other half required a "no" answer. Questions were distributed evenly such that half required a response that referenced the beginning of the sentence and the other half required a response that related to the end of the sentence. Six 69-item lists were created, each containing 32 experimental items (eight for each condition), 32 fillers, and the five practice sentences. Each list contained exactly one version of each of the 48 experimental sentence item sets. Within each file, eight item blocks were created, each containing eight sentences (four experimental items and four fillers). The blocks as well as the experimental items included in each block were presented in random order to each participant with the constraint that no two sentences representing the same condition were presented immediately following one another. This resulted in the items being presented to each participant in a different order, yet the items belonging to each stimulus type were evenly distributed throughout the duration of the experiment.

Procedure

Stimuli were presented on a color monitor using an EyeLink 1000 desktop-mounted eye-tracker (SR Research Ltd.) interfaced with an IBM-compatible PC. Participants sat in front of the computer screen and used a chin rest and a forehead pad to minimize head movement. Eye movements were recorded with a camera and an infrared illuminator, located at the bottom of the computer monitor. Viewing was binocular and monocular tracking of the right pupil and cornea was performed at a sampling rate of 1000 Hz. The eye-tracker was calibrated and validated for each participant at the beginning of the experimental block and after each break to calculate overall equipment accuracy. Following calibration, eye position errors were less than 0.3′. Bilinguals were seated 60 cm away from a 20-in. CRT monitor with 1280 × 1024 pixel resolution. At the start of the experiment, participants completed a nine-point calibration and validation procedure to allow monitoring of both horizontal and vertical eye movements. At the start of each trial, a calibration point (65 pixels wide and 85 pixels tall) appeared in the left corner of the screen, where the first word would appear. When a fixation was detected in this calibration point, it disappeared and was replaced by the sentence. Sentences appeared in 14-point Consolas font and were always presented in one line of text with 3.8 characters subtending one degree of visual angle. Participants were instructed to read each sentence silently at their own pace. After reading the sentence, participants were asked to answer a comprehension question related to the content of the sentence. The questions were answered with either "yes" or "no" by pressing one of two buttons on a game pad. In addition to the eye-tracking experiment proper, participants completed the three tasks (i.e., LHQ, BNT, grammar tests) that were used to assess language background and proficiency. These tasks were completed after the eye-tracking experiment. Participants were paid $10 per hour for their participation in the study.

Results

We report on the results of two eye-tracking reading measures for five regions of interest. In example (6) below, forward slashes indicate where the sentences were segmented for analysis:

(6)	*El chef piensa que/*	*los turistas/*	are/	enjoying/	the/	food/...
	Region 1	Region 2		Region 3	Region 4	Region 5

Region 1, the sentence initial region, combined the first four words in the sentence (Det + N + Main Verb + Comp). Region 2, the embedded subject (Det + N), included words 5 and 6 and constituted the region immediately preceding the critical region. Analyses on Region 1 and Region 2 were conducted to rule out the possibility that any differences on the critical region across conditions was caused by extraneous factors prior to the critical region. Region 3, the participle, was selected as the critical region because

[2] Lexical frequencies for the Spanish grammatical subjects of the embedded clauses are from the Alameda and Cuetos (1995) two-million-word corpus, and they were obtained through the Normas e índices de interés en Psicología Experimental (NIPE) website (Díez, Fernández, & Alonso, 2006).

[3] Lexical frequencies for the participles of the embedded clauses are from the HAL frequency norms (Lund & Burgess, 1996), based on one million words, and they were obtained through The English Lexicon Project website (Balota et al., 2007).

Table 4
Example of experimental item set.

Condition	Sample sentence
(1) Progressive – Switch at auxiliary	*El chef piensa que los turistas* are enjoying the food at his gourmet restaurant.
(2) Progressive – Switch at participle	*El chef piensa que los turistas están* enjoying the food at his gourmet restaurant.
(3) Perfect – Switch at auxiliary	*El chef piensa que los turistas* have enjoyed the food at his gourmet restaurant.
(4) Perfect – Switch at participle	*El chef piensa que los turistas han* enjoyed the food at his gourmet restaurant.

it is the point in the sentence at which the participants have processed the complete auxiliary phrase. It is also the point at which all code-switches, both the code-switches at the auxiliary and the code-switches at the participle, have occurred. We initially included the auxiliary as a region for analysis; however, models did not converge due to high levels of skipping (28% for progressive structures and 29% for perfect structures) and because the auxiliary always appeared as one of four forms: *están*/*are* for progressive structures and *han*/*have* for perfect structures. Unsurprisingly, deficient models essentially revealed that readers were affected by the length of the auxiliary: longer auxiliaries (i.e., *están* and *have*) were always read more slowly than shorter ones (i.e., *are* and *han*). We also analyzed the two words after the critical region (Region 4 and Region 5, respectively). Because processing is not always completed by the time the eyes move, the time spent processing a word (or region) can spill over to the next word (Rayner & Duffy, 1986). Therefore, analyses on Regions 4 and 5 were carried out to determine whether effects not observed on the critical region surfaced at a later point in the sentence and to determine whether any effects found on the critical region persisted through subsequent regions.

The two eye-tracking reading measures extracted for analysis were first-pass reading time and total time. First-pass reading time is defined as the sum of all the fixations within an interest area starting with the first fixation into that interest area until the first time the participant's gaze leaves the region either to the left or to the right (Rayner, 1998).[4] This measure was selected over first fixation duration because past work shows that both measures yield similar results (Rayner, 1998) and because first-pass reading time best captures the cognitive operations in multi-word regions. Total time represents the sum of all fixation durations in the critical region, including all regressive fixation durations on it (Rayner & Duffy, 1986).

We analyzed the two reading measures using generalized linear mixed-effects models as implemented by the lme4 package version 1.1–7 (Bates, Maechler, Bolker, & Walker, 2014) in the R Environment for Statistical Computing program, version 3.1.2 (R Core Team, 2014). Fixations shorter than 80 ms were combined with a previous or subsequent fixation if they were within one character of each other. Additionally, trials for which participants incorrectly answered the comprehension question were excluded from analysis, removing 9.6% of all experimental trials. A repeated measures ANOVA with auxiliary (progressive, perfect) as a within-subjects factor and group (early exposure, late exposure) as a between-subjects factor indicated that incorrect responses to the comprehension questions were evenly distributed across auxiliary and group (Auxiliary, $F(1,66) = 2.67$, $p = .11$; Group, $F(1,66) = 1.12$, $p = .29$; Auxiliary $*$ Group, $F(1,66) = 0.18$, $p = .67$).

We included Switch Position (at auxiliary, at participle), Group (early exposure code-switchers, late exposure code-switchers) and Auxiliary Type (progressive, perfect), and their interaction terms as fixed effects in the linear mixed-effects models. All factors were coded with contrast coding ($-.5$ for switches at the auxiliary, late exposure code-switchers, and progressive auxiliary). For the random effects structure, we first began by including random slopes for Switch Position, Auxiliary Type and their interaction as well as random intercepts on Subjects and random slopes for Switch Position and random intercepts on Items, following a maximal random effects structure justified by the design (Barr, Levy, Scheepers, & Tily, 2013). If models did not converge, then the random effects structure subsequently included the removal of the interaction between random slopes for Switch Position and random intercepts on Subjects. Finally, if this model did not converge (one model), then a subsequent model that removed random slopes for Items was used. We indicate in the table summaries when models did not include the full random effects structure and report regression coefficients (b) and the t-values for each coefficient. We report regression coefficients as significant at the .05 level for t-statistic values greater than or equal to 1.96 (e.g., Schotter, Bicknell, Howard, Levy, & Rayner, 2014). In the text, we solely describe the results for first-pass reading time unless the analysis with total time led to a different result.

Sentence initial and embedded subject regions (Regions 1 and 2)

On Regions 1 and 2, we compare first-pass reading time and total time of two bilingual code-switching groups before encountering the code-switched portion of the sentences. For both regions, skipping rates ranged from 0% to 3% across all conditions and groups. For the sentence initial and the embedded subject regions, the results from the linear mixed-effects models only revealed a main effect for Group (Region 1: $b = -189.92$, $t = -2.07$; Region 2: $b = -133.67$, $t = -2.47$), indicating that the late exposure group read the initial Spanish regions more quickly than the early exposure group for both the progressive structure (Region 1: early exposure group – switches at auxiliary = 1088 ms, $SE = 45.98$, switches at participle = 1115 ms, $SE = 36.85$; late exposure group – switches at auxiliary = 891 ms, $SE = 31.81$, switches at participle = 873 ms, $SE = 36.17$; Region 2: early exposure group – switches at auxiliary = 632 ms, $SE = 26.64$, switches at

[4] On single-word regions, first-pass reading time is equivalent to the commonly reported "gaze duration" (Liversedge, Paterson, & Pickering, 1998; Traxler, Morris, & Seely, 2002).

participle = 491 ms, SE = 18.43; late exposure group – switches at auxiliary = 502 ms, SE = 16.77, switches at participle = 491 ms, SE = 18.43) and the perfect structure (Region 1: early exposure group – switches at auxiliary = 1140 ms, SE = 40.71, switches at participle = 1156 ms, SE = 48.23; late exposure group – switches at auxiliary = 828 ms, SE = 30.35, switches at participle = 889 ms, SE = 37.6; Region 2: early exposure group – switches at auxiliary = 633 ms, SE = 26.64, switches at participle = 652 ms, SE = 28.35; late exposure group – switches at auxiliary = 561 ms, SE = 21.55, switches at participle = 525 ms, SE = 21.66). Importantly, the models did not indicate any main effects or interaction with Switch Position or Auxiliary Type, suggesting no baseline differences leading up to the code-switched region. Full model outputs for both regions are reported in Tables 5 and 6.

Critical region (Region 3)

On the critical region, we compare first-pass reading time and total time of the two participant groups when encountering code-switches that occur with progressive (i.e., *are*/*están*) or perfect (i.e., *have*/*han*) structures. Skipping rates for trials including the progressive structure averaged 4% (range: 2–7%) and those for trials including the perfect structure averaged 3% (range: 2–5%). Mean reading times and standard error for the critical region are shown in Table 7. The results of the linear mixed-effects models for the two reading time measures are included in Table 8.

The final model revealed a Switch Position ∗ Auxiliary Type interaction (b = 85.18, t = 2.31) and no other main effects or interactions. In order to explore this interaction further, we conducted post hoc comparisons using Tukey's HSD as instantiated in the multcomp package version 1.4-1 in R (Hothorn, Bretz, & Westfall, 2008). The post hoc tests revealed a significant difference between code-switches at the participle (*los turistas* <u>han enjoyed</u>) and code-switches at the auxiliary (*los turistas* <u>have enjoyed</u>) for perfect structures (p < .001). Crucially, there was no significant difference between the progressive structure code-switches (p = .13). Post-hoc tests with total time further revealed a significant difference between perfect and progressive code-switches at the participle (*los turistas* <u>*están* enjoying</u>/<u>*han* enjoyed</u>, p < .001). Mean reading times and standard errors for both reading measures are plotted in Figs. 2 and 3.[5]

First and second words post-participle (Regions 4 and 5)

In the word immediately following the critical region, participants exhibited high skipping rates across all conditions (range: 44–58%), likely due to the immediately following word being a determiner or another function word.[6] The linear mixed-effects model that included first-pass reading time as a dependent variable did not reveal any main effects or interactions (all ts < |1.63|). In contrast, the interaction between Switch Position and Auxiliary Type was significant for total time (Switch Position ∗ Auxiliary Type: b = 72.14, t = 2.27). Post hoc tests with Tukey's HSD indicated a significant difference between code-switches involving the perfect structure (*los turistas* <u>have enjoyed</u>/<u>*han* enjoyed</u>), with switches at the participle taking longer to read than switches at the auxiliary (p < .001). Additionally, code-switches at the participle involving perfect structures (*los turistas* <u>*han* enjoyed</u>) were significantly slower than those involving the progressive structure (*los turistas* <u>*están* enjoying</u>, p < .001). As in the case of the critical region, the difference between the progressive structure code-switched conditions was not significant (p = .56). Mean reading times and standard errors for the first word post-participle region are reported in Table 9 and are plotted for first-pass reading and total time in Figs. 4 and 5 respectively.

In the second word following the participle, skipping rates ranged between 9% and 11% with a mean skipping rate of 9% for sentences including the progressive structure and 10% for sentences including the perfect structure. The linear mixed-effects model only indicated a main effect for Group (b = 45.06, t = 1.99) for first-pass reading time, such that the early exposure group read this region more quickly than the late exposure group in sentences with the progressive structure (early exposure group – switches at auxiliary = 275 ms, SE = 11.55, switches at participle = 290 ms, SE = 12.08; late exposure group – switches at auxiliary = 315 ms, SE = 15.43, switches at participle = 349 ms, SE = 18.45) and in sentences with the perfect structure (early exposure group – switches at auxiliary = 273 ms, SE = 11.21, switches at participle = 293 ms, SE = 12.33; late exposure group – switches at auxiliary = 314 ms, SE = 14.06, switches at participle = 321 ms, SE = 16.82). No other main effects or interactions were significant, and the main effect for Group was not significant for total time (b = 25.48, t = 0.55, switches at auxiliary with progressive structure = 511 ms, SE = 16.65, switches at participle with progressive structure = 535 ms, SE = 20.02; switches at auxiliary with perfect structure = 525 ms, SE = 18.37, switches at participle with perfect

[5] Because Group was not a significant effect, we present mean reading times collapsed for group.

[6] We conducted a repeated measures ANOVA including Switch Position and Auxiliary Type as within-subjects factors and Group as a between-subjects factor. This test revealed a main effect for Switch Position (F(1,66) = 5, p = .03, η^2 = 0.01) and a marginal effect for Auxiliary Type (F(1,66) = 3.29, p = .07, η^2 = 0.01), indicating that participants exhibited higher skipping rates for switches at the auxiliary (M = 55%) than for switches at the participle (M = 50%) as well as a similar trend for progressive structures (M = 55%) and perfect structures (M = 50%). Although it is difficult to determine why participants exhibited differential skipping across factors, we speculate that this pattern of results reflects easier processing in conditions that exhibit higher skipping, i.e., with function words that are highly supported by their sentence context (Rayner, 1998).

Table 5
Results of the linear mixed-effects models for the sentence initial region (Region 1).

Measure	Variable	*b*	*SE*	*t*
First-pass	Intercept	1097.18	62.35	**17.6**
	Switch Position	28.12	42.2	0.62
	Auxiliary Type	52.51	55.94	0.94
	Group	−189.92	91.66	**−2.07**
	Switch Position * Auxiliary	−21.81	62.08	−0.35
	Switch Position * Group	−65.58	72.56	−0.9
	Auxiliary * Group	−136.1	71.23	−1.91
	Switch Position * Auxiliary * Group	134.09	99.43	1.35
Total time	Intercept	2436.9	142.22	**17.13**
	Switch Position	−4.35	118.5	−0.04
	Auxiliary Type	65.02	138.19	0.47
	Group	−658.39	215.71	**−3.05**
	Switch Position * Auxiliary	−114.12	159.9	−0.71
	Switch Position * Group	−5.96	179.5	−0.03
	Auxiliary * Group	−37.43	197.79	−0.19
	Switch Position * Auxiliary * Group	192.02	240.61	0.8

Results for the linear mixed-effects models on first-pass reading time and total time. All predictor variables were contrast coded (−0.5 = switch at auxiliary; progressive auxiliary; late exposure group). Significant *t*-values are bolded.

Table 6
Results of the linear mixed-effects models for the embedded subject region (Region 2).

Measure	Variable	*b*	*SE*	*t*
First-pass	Intercept	638.44	39.56	**16.14**
	Switch Position	15.28	33.76	0.45
	Auxiliary Type	−0.77	40.91	−0.02
	Group	−133.67	54.06	**−2.47**
	Switch Position * Auxiliary	−3.63	45.64	−0.08
	Switch Position * Group	−16.63	50.81	−0.33
	Auxiliary * Group	53.67	46.52	1.15
	Switch Position * Auxiliary * Group	−25.08	68.2	−0.37
Total time	Intercept	1221.11	75.51	**16.17**
	Switch Position	−34.4	64	−0.54
	Auxiliary Type	56.02	80.7	0.69
	Group	−281.69	106.53	**−2.64**
	Switch Position * Auxiliary	−30.85	83.11	−0.37
	Switch Position * Group	17.73	96.34	0.18
	Auxiliary * Group	39.16	101.62	0.39
	Switch Position * Auxiliary * Group	38.13	123.5	0.31

Results for the linear mixed-effects models on first-pass reading time and total time. All predictor variables were contrast coded (−0.5 = switch at auxiliary; progressive auxiliary; late exposure group). Significant *t*-values are bolded.

structure = 555 ms, *SE* = 19.31). Full model outputs for both regions are reported in Tables 10 and 11.[7]

To summarize, bilinguals demonstrated an asymmetry in how they process code-switched sentences with the perfect structure vis-à-vis code-switched sentences with the progressive structure. Specifically, in both early and late reading measures, Spanish–English bilinguals were slower while reading code-switches at the participle that involved the perfect auxiliary (*los turistas* *han* enjoyed) than those at the auxiliary (*los turistas* have enjoyed). This processing difficulty extended to the word immediately following the participle for total time, indicating that the processing difficulty is not short-lived, and it dissipated in the second word after the participle. Importantly, the differences in fixation durations between the two conditions are not present prior to the critical region. Analyses of pre-critical regions revealed group differences, but these reflected language dominance, i.e., the late exposure group, as Spanish-dominant speakers, read the Spanish portion of the sentences more quickly than the early exposure group, and the early exposure group, as English-dominant speakers, began to read the English portion of the sentences more quickly than the late exposure group. Results for the perfect structure are different from those for the progressive structure, in which no significant differences between switches at the auxiliary relative to switches at the participle were found in any of the five regions examined. Critically, the asymmetric behavior observed in the comprehension of the perfect and progressive code-switches reflects the statistical regularities found in code-switching corpora; this provides support for the

[7] We note that the results for the combined regions (i.e., one two-word region) did not reveal any significant main effects or interactions for either first-pass reading time or total time, likely indicating that the spillover interaction effect from the critical region is short-lived and that the Group effect on the second word of the post-participle region is an emergent effect.

Table 7
Mean reading times and standard error on the critical region (participle, Region 3).

Measure	Switch Position	Late Exposure	Early Exposure
Progressive structure, e.g., *los turistas* are enjoying, *los turistas están* enjoying			
First-pass	At Auxiliary	368 (16.75)	350 (14.78)
	At Participle	409 (18.83)	388 (14.49)
Total time	At Auxiliary	674 (29.78)	683 (34.97)
	At Participle	732 (40.31)	750 (29.09)
Perfect structure, e.g., *los turistas* have enjoyed, *los turistas han* enjoyed			
First-pass	At Auxiliary	355 (16.59)	311 (11.95)
	At Participle	440 (24.60)	438 (19.10)
Total time	At Auxiliary	679 (36.05)	636 (26.71)
	At Participle	952 (46.12)	947 (39.32)

Mean reading times in milliseconds for first-pass reading time and total time split by bilingual group with standard error presented in parentheses. Progressive conditions appear in the upper panel and Perfect conditions are presented in the lower panel.

Table 8
Results of the linear mixed-effects models for the critical region (participle, Region 3).

Measure	Variable	*b*	*SE*	*t*
First-pass[a]	Intercept	348.75	24.83	**14.05**
	Switch Position	40.72	24.35	1.67
	Auxiliary Type	−39.1	24.74	−1.58
	Group	24.46	36.77	0.67
	Switch Position ∗ Auxiliary	85.18	36.93	**2.31**
	Switch Position ∗ Group	1.52	38.94	0.04
	Auxiliary ∗ Group	18.78	33.71	0.56
	Switch Position ∗ Auxiliary ∗ Group	−35.8	58.91	−0.61
Total time	Intercept	681.28	51.02	**13.35**
	Switch Position	72.37	40.39	1.79
	Auxiliary Type	−41.1	52.41	−0.78
	Group	11.33	72.09	0.16
	Switch Position ∗ Auxiliary	241.17	64.55	**3.74**
	Switch Position ∗ Group	−15.89	64.68	−0.25
	Auxiliary ∗ Group	27.84	64.69	0.43
	Switch Position ∗ Auxiliary ∗ Group	−17.5	102.98	−0.17

Results for the linear mixed-effects models on first-pass reading time and total time. All predictor variables were contrast coded (−0.5 = switch at auxiliary; progressive auxiliary; late exposure group). Significant *t*-values are bolded.
[a] The model that converged with first-pass reading time included random intercepts for Items.

hypothesis that bilinguals are sensitive to the way both structures are code-switched in production.

General discussion

The way that bilingual speakers fluidly navigate between languages within a conversation presents bilingual listeners with unique challenges; because bilinguals purportedly do not provide obvious and explicit signals that they are about to produce a code-switch into the other language, the comprehension of code-switches can potentially be quite difficult due to increased ambiguity between linguistic forms. Indeed, it has been established in prior work on code-switching that processing switches incurs costs, although there is also evidence that these costs can be mitigated. What, then, makes some code-switches easier for bilinguals to recognize and other code-switches more difficult? Our approach to begin to answer this question involved identifying statistical regularities that emerge in the production of code-switching, which subsequently may be informative to bilinguals during comprehension. To address this, we capitalized on a distributional asymmetry[8] in the production of code-switches involving the auxiliary phrase: whereas the Spanish auxiliary *estar* co-occurs with English participles in code-switched speech, the Spanish auxiliary *haber* rarely does. We examined whether these statistics could provide some advantage while two groups of bilinguals (bilinguals exposed to code-switching from an early age and bilinguals first exposed to code-switching as young adults) processed the two types of code-switches during reading. Our findings indicate that for both bilingual groups, comprehension costs that surfaced during reading mirrored the production

[8] Asymmetries like this are not unique. In Spanish–English code-switching, grammatical gender assignment also displays production asymmetries: whereas Spanish masculine prenominal modifiers appear with English nouns whose Spanish translation equivalent is masculine (el_{MASC} shoe/el_{MASC} $zapato_{MASC}$) or feminine (el_{MASC} $blender_{FEM}$/la_{FEM} $licuadora_{FEM}$), feminine prenominal modifiers only appear with English words whose Spanish translation equivalent is feminine (la_{FEM} $blender_{FEM}$, but not la_{FEM} $shoe_{MASC}$, Valdés Kroff, in press; Valdés Kroff, Dussias, Gerfen, Perrotti, & Bajo Molina, in press).

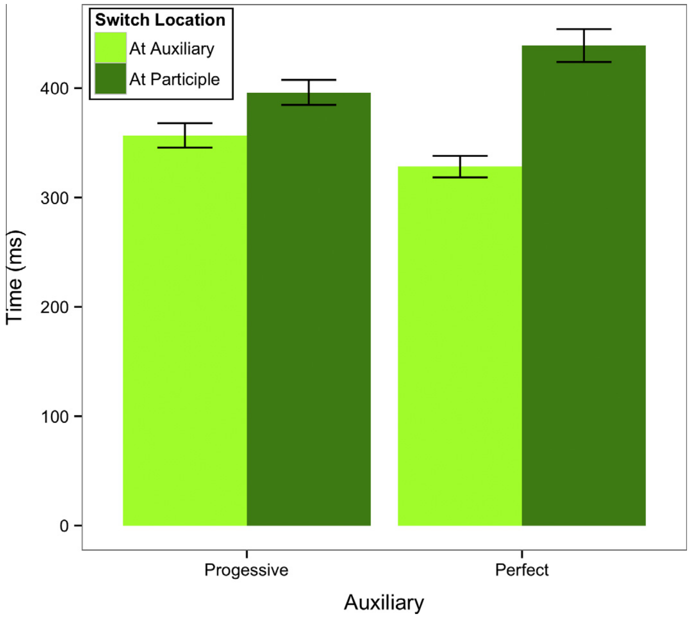

Fig. 2. Mean first-pass reading time on the critical region (participle, Region 3). Mean reading times in milliseconds are presented for first-pass reading time on the participle for code-switches involving the progressive (*are/están*) and perfect (*have/han*) structures collapsed for bilingual group. For each auxiliary type, switches at the auxiliary (*los turistas* are enjoying/have enjoyed) are presented on the left. Error bars represent standard error of the mean.

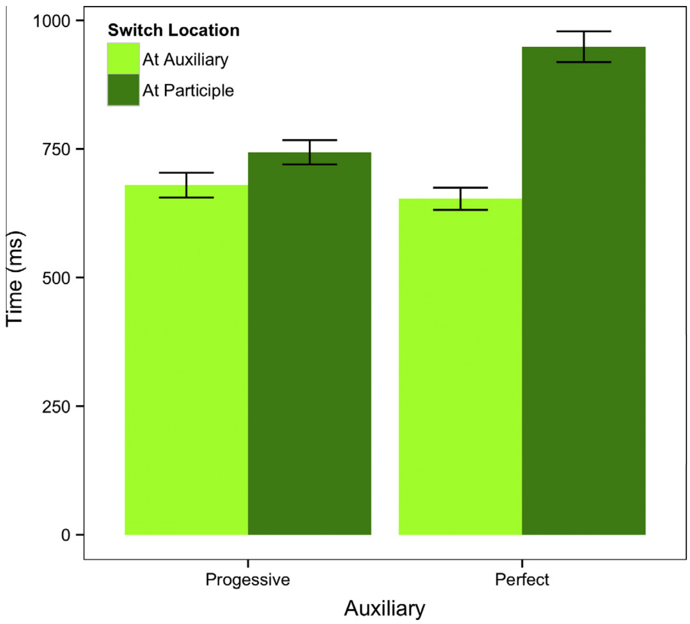

Fig. 3. Mean total time on the critical region (participle, Region 3). Mean reading times in milliseconds are presented for total time on the participle for code-switches involving the progressive (*are/están*) and perfect (*have/han*) structures collapsed for bilingual group. For each auxiliary type, switches at the auxiliary (*los turistas* are enjoying/have enjoyed) are presented on the left. Error bars represent standard error of the mean.

patterns found in code-switching corpora: switches at the participle were more costly when they involved *haber* plus an English participle. The fact that both groups of bilinguals behaved similarly highlights the importance of usage-based accounts of learning (Bybee, 2006), given that in these accounts language emerges not as a result of language-specific mechanisms, but through the interaction of cognition and use (Ibbotson, 2013).

One methodological aspect of our study merits some attention. Our design necessarily required that the experimental items differ in important respects. Thus, we employed structures that were entirely different (present

Table 9
Mean reading times and standard error on the first word post-participle region (Region 4).

Measure	Switch Position	Late Exposure	Early Exposure
Progressive structure, e.g., *los turistas* are enjoying, *los turistas están* enjoying			
First-pass	At Auxiliary	107 (9.97)	129 (10.02)
	At Participle	117 (13.23)	131 (9.35)
Total time	At Auxiliary	207 (16.02)	239 (15.5)
	At Participle	248 (20.71)	250 (17.28)
Perfect structure, e.g., *los turistas* have enjoyed, *los turistas han* enjoyed			
First-pass	At Auxiliary	108 (9.89)	123 (8.68)
	At Participle	158 (15.74)	162 (11.39)
Total time	At Auxiliary	263 (27.65)	243 (14.77)
	At Participle	347 (29.66)	332 (18.43)

Mean reading times in milliseconds for first-pass reading time and total time split by bilingual group with standard error presented in parentheses. Progressive conditions appear in the upper panel and perfect conditions are presented in the lower panel.

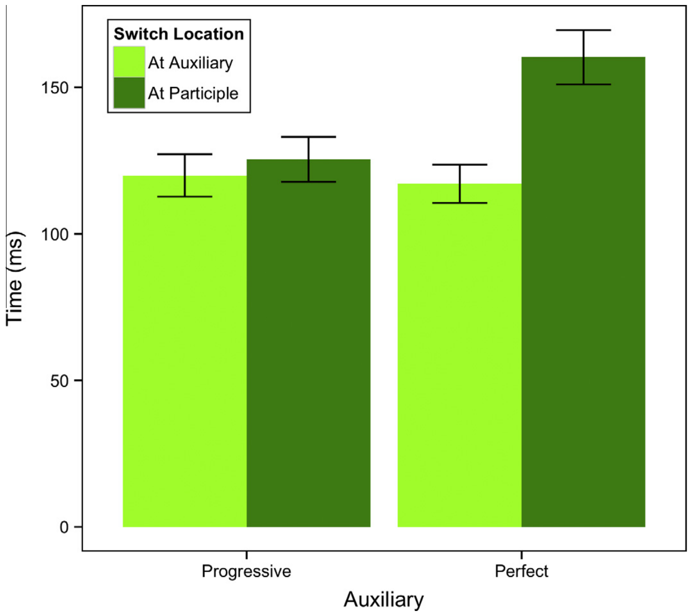

Fig. 4. Mean first-pass reading time on the first word post-participle region (Region 4). Mean reading times in milliseconds are presented for first-pass reading time on the first word post-participle for code-switches involving the progressive (*are/están*) and perfect (*have/han*) structures collapsed for bilingual group. For each auxiliary type, switches at the auxiliary (*los turistas* are enjoying/have enjoyed) are presented on the left. Error bars represent standard error of the mean.

perfect vs. present progressive); the English participles within each structure have different morphological make-ups (enjoy-ed vs. enjoy-ing) and also different distributional statistics in English; the auxiliaries appeared in different languages (are-*están*-have-*han*) and differed in their morphological structure in important ways (e.g., the -a in *están* denotes the morphological class of the verb and the -n denotes person and number; the English auxiliaries are morphologically simpler). Although these differences could be a source of concern, in our view, the very fact that the results turned out in the predicted direction in spite of the differences between the two structures underscores the central role of statistics in linguistic distributions for comprehension behavior. Furthermore, as the first spillover region continued to show the same pattern of results found in the critical region (i.e., no significant difference between the progressive conditions, but a significant difference between the perfect conditions), we interpret the overall results to indicate that the difference in the perfect conditions is due to increased difficulty for code-switches at the participle.

Why production asymmetries?

We return to the question of what factors may be responsible for the production asymmetries of the two types of code-switches observed in the corpus data. One possibility is that the differences in production arise from differences in the way that the two structures are used in Spanish and English. Specifically, the perfect structure

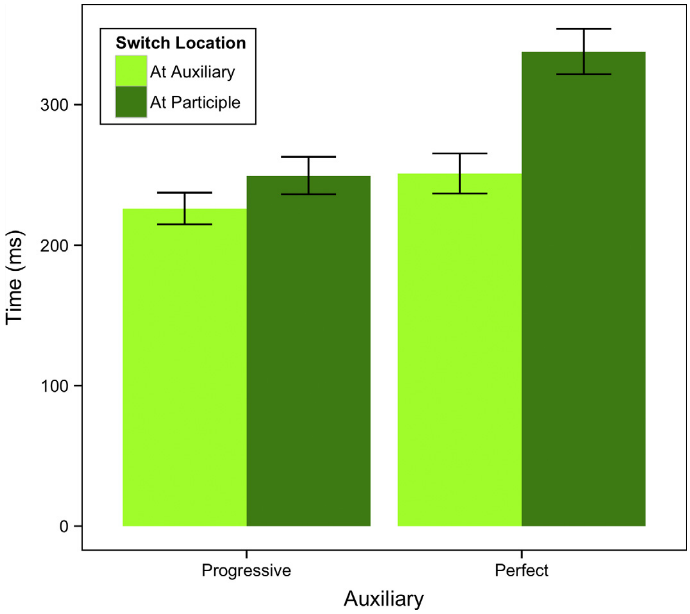

Fig. 5. Mean total time on the first word post-participle region (Region 4). Mean reading times in milliseconds are presented for total time on the first word post-participle for code-switches involving the progressive (*are/están*) and perfect (*have/han*) structures collapsed for bilingual group. For each auxiliary type, switches at the auxiliary (*los turistas* are enjoying/have enjoyed) are presented on the left. Error bars represent standard error of the mean.

Table 10
Results of the linear mixed-effects models for the first word post-participle region (Region 4).

Measure	Variable	*b*	*SE*	*t*
First-pass	Intercept	130.46	13.99	**9.33**
	Switch Position	3.74	13.18	0.28
	Auxiliary Type	−6.47	16.94	−0.38
	Group	−20.17	18.63	−1.08
	Switch Position ∗ Auxiliary	32.1	18.59	1.73
	Switch Position ∗ Group	5.16	20.89	0.25
	Auxiliary ∗ Group	0.91	20.73	0.04
	Switch Position ∗ Auxiliary ∗ Group	13.04	29.39	0.44
Total time	Intercept	241.08	26.22	**9.19**
	Switch Position	10.33	22.21	0.47
	Auxiliary Type	8.61	31.49	0.27
	Group	−29.02	34.62	−0.84
	Switch Position ∗ Auxiliary	72.14	31.8	**2.27**
	Switch Position ∗ Group	30.11	35.63	0.85
	Auxiliary ∗ Group	45.79	37.73	1.21
	Switch Position ∗ Auxiliary ∗ Group	−27.56	50.88	−0.54

Results for the linear mixed-effects models on first-pass reading time and total time. All predictor variables were contrast coded (−0.5 = switch at auxiliary; progressive auxiliary; late exposure group). Significant *t*-values are bolded.

can be used with deictic adverbial complements (e.g., *hoy* 'today') in certain varieties of Spanish—particularly in Peninsular varieties—to express simultaneity to the present moment; however, this use is not possible in English (Markle LeMontagne, 2011). This is illustrated in examples (8) and (9).

(8)	*Hoy he llamado a mi madre.*
(9)	*Today I have called my mother.

If equivalence facilitates code-switching (Poplack, 1980, 2015), the difference between the perfect structure in Spanish and English may block the occurrence of a code-switch. This hypothesis does not seem tenable, however, once we consider that Spanish and English also display differences in the progressive structure. For example, whereas in English the present progressive can be used to refer to a future action, as shown in example (10), in Spanish the use of the progressive structure to signal future is barred, as exhibited in example (11). Future in Spanish is expressed either with a future marker on the verb (comer-*é* '(I) will eat') or with a periphrastic construction (*vamos a viajar* la próxima semana '(we) go to [= will] travel next week').

(10)	Tomorrow we are eating at 1:00 p.m.
(11)	**Mañana estamos comiendo a la 1:00 p.m.*

Table 11
Results of the linear mixed-effects models for the second word post-participle region (Region 5).

Measure	Variable	*b*	*SE*	*t*
First-pass	Intercept	277.02	17.57	**15.77**
	Switch Position	16.73	16.4	1.02
	Auxiliary Type	−1.19	21.5	−0.06
	Group	45.06	22.69	**1.99**
	Switch Position ∗ Auxiliary	4.09	23.6	0.17
	Switch Position ∗ Group	9.17	25.9	0.35
	Auxiliary ∗ Group	−1.9	25.23	−0.08
	Switch Position ∗ Auxiliary ∗ Group	−21.7	37.18	−0.58
Total time	Intercept	505.45	39.46	**12.81**
	Switch Position	11.25	31.7	0.36
	Auxiliary Type	21.97	48.01	0.46
	Group	25.48	46.69	0.55
	Switch Position ∗ Auxiliary	20.89	41.9	0.5
	Switch Position ∗ Group	27.35	50.41	0.54
	Auxiliary ∗ Group	7.7	48.04	0.16
	Switch Position ∗ Auxiliary ∗ Group	−23.38	66.41	−0.35

Results for the linear mixed-effects models on first-pass reading time and total time. All predictor variables were contrast coded (−0.5 = switch at auxiliary; progressive auxiliary; late exposure group). Significant *t*-values are bolded.

If the differences between the perfect and the progressive structures in English and Spanish create environments that are not propitious for code-switches to occur, we would not expect the production patterns reported in corpus studies to look the way they do. Moreover, our corpus study and our eye-tracking experiment included only cases where the two languages could combine at any level of linguistic structure and use, and where the consequences of such combinations would not result in semantic incompatibilities between the two languages.

If there are no differences in meaning or in use linked to the occurrence of code-switches involving the progressive and the perfect structures, how can we explain the differences in their distributional patterns? The 4-M model of code-switching (Myers-Scotton & Jake, 2001), explained briefly in the 'Introduction' section, discusses the differential participation of closed-class items in code-switching, and the resulting production asymmetries, by classifying closed-class items (including auxiliaries) in terms of how and when they are activated during language production. The model, which is based on Levelt's (1989) speech production model, takes as a starting point the observation that language specific properties can interact with production mechanisms to lead to differences with regard to information flow during sentence production (Vigliocco, Butterworth, & Garrett, 1996)—an observation that has received independent support from prior cross-linguistic research (e.g., Costa, Sebastián-Gallés, Miozzo, & Caramazza, 1999; Miozzo & Caramazza, 1999; Schiller & Caramazza, 2003). Lexical access and grammatical encoding during production are located in the formulation component (Levelt, 1989). This component takes a speaker's non-linguistic conceptual message and transforms it into linguistic structure. Words are accessed and ordered, and their sounds are retrieved and organized for articulation. The formulation component is distinguished from a prior component responsible for message formation (the conceptualizer) and from a subsequent one that executes articulatory movements (Dell, Chang, & Griffin, 1999). The formulation component is commonly thought of as involving two stages, a functional stage of processing and a positional stage. During functional processing, speakers lexicalize concepts and generate functional structure (e.g., syntactic information is specified and syntactic roles are assigned). During positional processing, the retrieved lexical items are inflected and assembled into their appropriate position in the sentence (see Jaeger & Norcliffe, 2009). The output of these two stages is then passed onto the phonetic encoding and the articulatory processing (Bock & Levelt, 1994).

Returning now to the Spanish auxiliary system, according to Myers-Scotton and Jake (2001), not all closed-class items are equal. Early system morphemes are free to participate in code-switching, but late system morphemes, which are void of meaning and fulfill purely syntactic functions, are structurally assigned and, hence, do not easily participate in code-switching. The classification of *estar* as an early system morpheme and *haber* as a late system morpheme is based on their respective within-language behavior. Although both are poly-morphemic and convey tense and aspect, *haber* has lost its original meaning of 'to have,' or 'to possess' (Coromines & Pascual, 1980). Modern day Spanish expresses possession using *tener* (e.g., *él tiene una mascota* 'he has a pet'). New verbs have also replaced periphrastic uses of *haber*; hence, *haber alegría* 'to have happiness' is expressed in contemporary Spanish with *alegrarse*; *haber miedo* 'to have fright' has become *asustarse*, and *haber nombre* 'to have a name' is *llamarse* (García Gallarín, 2002, p. 20). In Spanish, *haber* as a lexical verb is only employed as an existential (*hay* *cinco libros* 'there are five books'), and in archaic (and non-productive) phrases to express obligation (e.g., has *de verla* 'you have to see her'). The argument is that *haber* is simply a "placeholder" for grammatical features to be expressed orthographically and phonologically during the positional stage in production. These properties of *haber* considerably limit the possibility of a code-switch to be produced. In contrast to *haber*, *estar* is more autonomous in its syntactic behavior. First, aside from being followed by the present participle (*estoy trabajando* 'I am working'), *estar* can be followed by other expressions, such as adverbial and adjectival phrases (e.g., *estoy en el parque* 'I am at the park,' and *estoy molesto* 'I am angry'). In addition, intervening material is permissible between *estar* and a present participle (e.g., *ella está* siempre *fastidiándonos* 'she is always bothering us'). *Estar* and the present participle can also switch syntactic positions, something not permissible with *haber* (e.g., *caminando estoy* 'walking (I) am'). This indicates that *estar* is semantically more autonomous, allowing for a code-switch to occur effortlessly in this context. If this analysis is correct, *estar* is salient at the level of the mental lexicon, and switches involving the *estar* + participle constructions should have no particular restrictions on their production, i.e., no restrictions against code-switching, as is the case in other well-attested syntactic positions, such as switches between a subject noun phrase and its corresponding verb phrase. *Haber*, on the other hand, has purely grammatical functions and is salient only when late selected morphemes are structurally-assigned; because of this, the entire *haber* verb phrase does not easily participate in code-switching.

Admittedly, the production explanation provided here remains necessarily tentative because our understanding of the production forces that promote code-switching is in a very early stage. One general, albeit counter-intuitive hypothesis, is that bilinguals engage in code-switching partly to improve production fluency. We know that bilinguals are actually not capable of "turning off" another language entirely, even when the intention is to speak one language only (Kroll, 2008; Kroll & Bialystok, 2013; Kroll, Bobb, & Wodniecka, 2006). Given the parallel activity of a bilingual's two languages, it may be that bilinguals code-switch, in part, to mitigate utterance planning difficulties that come from the parallel activation of their two languages. The fact that not all bilinguals code-switch suggests the presence of social forces and community-based norms that also affect whether or not bilinguals engage in code-switching (Myers-Scotton, 1993; Torres Cacoullos & Travis, 2015). But when code-switching is part of the linguistic repertoire of bilingual communities, it may be a strategy used to mitigate utterance planning difficulties that come from having words and sentence structures activated in parallel in both languages. In this sense, costs associated with the production of code-switches should be the exception and not the norm. We hope that the study of the relationship between the comprehension and production of code-switched language presented here has the consequence of increasing interest from production researchers to investigate the production forces that promote code-switching.

Linking production patterns to comprehension difficulty

The results of the eye-tracking study are congenial with models that propose that the relative frequency of constructions, as quantified within a corpus, modulates comprehension costs. The Production–Distribution–Comprehension (PDC) model (Gennari & MacDonald, 2009; MacDonald, 2013; MacDonald & Thornton, 2009) is one such model. According to the PDC model, the properties and mechanisms of the production system influence the structural choices that individuals make during production, promoting certain lexical or structural pairings over others. These production pressures, over time and across many speakers and writers, create distributional patterns in the language input that comprehenders perceive. The distributional patterns become the probabilistic constraints that guide comprehension in a constraint-based system. Comprehenders implicitly learn from these patterns and interpret new input as consistent with previous experience. Therefore, factors beyond the structural properties of language, such as prior experience with particular structures, are considered to play a crucial role in the comprehension of those structures. In other words, frequent linguistic structures are more readily activated than less common structures, and are, therefore, easier to process during comprehension. A similar notion is taken up in the P-chain framework (Dell & Chang, 2014), which discusses the relation between psycholinguistic concepts, such as processing, prediction, and production. A central aspect of the framework for the purposes of this study is the proposal that processing involves prediction regarding upcoming structures and that this prediction is influenced by the production systems of other speakers, which create production-biased distributions that train comprehenders' processing systems. This experience in predicting, in turn, trains production, resulting in a system in which both production and comprehension are linked to each other and affected by previous linguistic experience.

Both of these approaches can be invoked to explain the eye-tracking results reported here. As the corpus study showed, switches at the auxiliary involving the progressive structure are as frequent in the bilinguals' linguistic experience (be it others' production practices or their own) as switches at the participle; switches involving the perfect structure, however, are frequent if they occur at the auxiliary, but infrequent at the participle. The relative frequency of these switches in production obviously plays a key role. What is striking about the findings is the evidence that bilinguals have developed sensitivity to detailed distributional information about these two types of code-switches and that *this* modulates the bilinguals' comprehension difficulty.

In concluding, a word is in order about the importance of converging evidence. Over forty years of sentence-processing research has given rise to multiple models about the architecture of the sentence-processing mechanism. For the vast majority of this period, the evidential base in favor of one model or another has come from studies involving monolingual speakers. During this time, many creative experimental designs using powerful data collection tools have generated results that have been used to adjudicate among competing models. As might be expected, some results are firmly in the camp that proposes one particular model, but, of course, there is an extensive body of work that also favors an opposing model. In the very end, the model that will prevail is likely to be the one capable of accounting for the most findings. The work we presented here illustrates how we can expand the study of basic language processes by exploiting the presence of two languages in a single mind. Our findings broadly suggest that bilingual code-switchers learn and store frequency information about multi-word code-switches, which they later use during comprehension. By looking at bilingual data, then, we add evidence to the processing literature that broadly supports a usage-based position.

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Appendix A. Experimental item sets

El abogado descubrió que los criminales are bribing/están bribing/have bribed/han bribed the policeman to destroy the evidence.
'The lawyer discovered that the criminals...'

El abogado garantizó que los criminales are improving/están improving/have improved/han improved their behavior in jail.
'The lawyer guaranteed that the criminals...'

El arquitecto supone que los pintores are considering/están considering/have considered/han considered the colors for the house.
'The architect supposes that the painters...'

El carcelero dijo que los prisioneros are washing/están washing/have washed/han washed their clothes for the week.
'The warden said that the prisoners...'

El chef piensa que los turistas are enjoying/están enjoying/have enjoyed/han enjoyed the food at his gourmet restaurant.
'The chef thinks that the tourists...'

El compositor dice que los pianistas are practicing/están practicing/have practiced/han practiced the symphony for the concert.
'The composer says that the pianists...'

El consejero dijo que sus estudiantes are presenting/están presenting/have presented/han presented their results at the conference.
'The adviser said that his/her students...'

El contador cree que los banqueros are negotiating/están negotiating/have negotiated/han negotiated the loan for the clients.
'The accountant believes that the bankers...'

El contador piensa que los banqueros are preparing/están preparing/have prepared/han prepared the report for the supervisors.
'The accountant thinks that the bankers...'

El decano notó que las recepcionistas are filing/están filing/have filed/han filed the applications in alphabetical order.
'The dean noticed that the receptionists...'

El director afirmó que los técnicos are repairing/están repairing/have repaired/han repaired the photocopiers in the school library.
'The principal affirmed that the technicians...'

El director dijo que los instructores are preparing/están preparing/have prepared/han prepared the exam for the students.
'The principal said that the instructors...'

El director dijo que los productores are preparing/están preparing/have prepared/han prepared the set for the movie.
'The director said that the producers...'

El dueño dijo que los arquitectos are signing/están signing/have signed/han signed the documents for the construction.
'The owner said that the architects...'

El editor notó que los voluntarios are arranging/están arranging/have arranged/han arranged the photographs for the Entertainment section.
'The editor noticed that the volunteers...'

El empleado supone que sus colegas are notifying/están notifying/have notified/han notified their boss of the accident.
'The employee supposes that his colleagues...'

El entrenador dijo que los atletas are ignoring/están ignoring/have ignored/han ignored the remarks from the opposing team.
'The coach said that the athletes...'

El entrenador mencionó que los atletas are practicing/están practicing/have practiced/han practiced five hours a day.
'The coach said that the athletes...'

(*continued on next page*)

El entrenador notó que los atletas are grabbing/están grabbing/have grabbed/han grabbed their uniforms from the pile.
'The coach noticed that the athletes...'

El entrenador piensa que los atletas are celebrating/están celebrating/have celebrated/han celebrated their win at the bar.
'The coach thinks that the athletes...'

El general mencionó que los veteranos are enjoying/están enjoying/have enjoyed/han enjoyed the celebration in their honor
'The general mentioned that the veterans...'

El gerente notó que los turistas are enjoying/están enjoying/have enjoyed/han enjoyed their stay in the hotel.
'The manager noticed that the tourists...'

El guardia dijo que los prisioneros are cooking/están cooking/have cooked/han cooked the food in the kitchen.
'The guard said that the prisoners...'

El investigador piensa que los gánsters are shipping/están shipping/have shipped/han shipped the drugs to New York City.
'The investigator thinks that the gangsters...'

El jefe anunció que las secretarias are notifying/están notifying/have notified/han notified the media about the strike.
'The boss announced that the secretaries...'

El locutor dijo que los entrenadores are reaching/están reaching/have reached/han reached their goals with the players.
'The announcer said that the trainers...'

El maestro notó que los estudiantes are copying/están copying/have copied/han copied the answers on their desks.
'The teacher noticed that the students...'

El periodista anunció que los músicos are producing/están producing/have produced/han produced the album in the studio.
'The journalist announced that the musicians...'

El presidente anunció que los senadores are negotiating/están negotiating/have negotiated/han negotiated the terms of the agreement.
'The president announced that the senators...'

El psiquiatra afirmó que los prisioneros are justifying/están justifying/have justified/han justified their behavior in the session.
'The psychiatrist affirmed that the prisoners...'

El reportero confirmó que los senadores are requesting/están requesting/have requested/han requested the funds for the project.
'The reporter confirmed that the senators...'

El reportero dijo que las modelos are signing/están signing/have signed/han signed a contract with the agency.
'The reporter said that the models...'

El sargento garantizó que los detectives are removing/están removing/have removed/han removed the evidence from the crime scene.
'The sergeant guaranteed that the detectives...'

El sargento garantizó que los soldados are preparing/están preparing/have prepared/han prepared the weapons for the mission.
'The sergeant guaranteed that the soldiers...'

El supervisor mencionó que los carpinteros are fixing/están fixing/have fixed/han fixed the cabinets in the kitchen.
'The supervisor mentioned that the carpenters...'

El vendedor confirmó que los coleccionistas are importing/están importing/have imported/han imported the sculptures from India.
'The seller confirmed that the collectors...'

La enfermera afirmó que los doctores are consulting/están consulting/have consulted/han consulted a specialist about the results.
'The nurse affirmed that the doctors...'

La enfermera descubrió que los cirujanos are deceiving/están deceiving/have deceived/han deceived the patient about his illness.
'The nurse discovered that the surgeons...'

La estilista confirmó que los diseñadores are organizing/están organizing/have organized/han organized their collections for the fashion show.
'The stylist confirmed that the designers...'

La familia notó que los jardineros are planting/están planting/have planted/han planted the trees in the backyard.
'The family noticed that the gardeners...'

La maestra supone que los estudiantes are checking/están checking/have checked/han checked their email in the library.
'The teacher supposes that the students...'

La profesora anunció que los editores are approving/están approving/have approved/han approved her article for the journal.
'The professor announced that the editors...'

La reportera afirmó que los científicos are testing/ están testing/have tested/han tested the vaccine on rats.
'The reporter affirmed that the scientists...'

La revista indicó que los actores are answering/están answering/have answered/han answered the letters from their fans.
'The magazine indicated that the actors...'

La secretaria dijo que los asistentes are accusing/están accusing/have accused/han accused their boss of fraud.
'The secretary said that the assistants...'

La superintendente garantiza que los instructores are testing/están testing/have tested/han tested the students appropriately.
'The superintendent guarantees that the instructors...'

Los estudiantes notaron que las profesoras are placing/ están placing/have placed/han placed their quizzes on the bookshelf.
'The students noticed that the professors...'

Los inquilinos notaron que los electricistas are fixing/ están fixing/have fixed/han fixed the powerlines in the building.
'The tenants noticed that the electricians...'

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