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Multiple Levels of Bilingual Language Control: Evidence from Language Intrusions in Reading Aloud

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Abstract

Bilinguals rarely produce words in an unintended language. However, we induced such intrusion errors (e.g., saying *el* instead of *he*) in 32 Spanish-English bilinguals who read aloud language-selective and language-mixed paragraphs with English or Spanish word order. Bilinguals produced language intrusions almost exclusively in language-mixed paragraphs, and most often when attempting to produce dominant-language targets (accent-only errors also exhibited reversed language dominance effects). Most intrusion errors occurred for function word targets, especially when they did not match paragraph language word order. Eye movements showed that fixating a word in the non-target language increased intrusion errors only for function word targets. Together, these results imply multiple mechanisms of language control, including (a) inhibition of the dominant language at both lexical (Green, 1998) and sublexical processing levels, (b) special retrieval mechanisms for function words in mixed-language utterances (Myers-Scotton, 1993), and (c) attention's role in monitoring target language for match with intended language.

Keywords

bilingualism; language control; reading aloud; speech error; intrusion error; eye movements

Proficient bilinguals have remarkable control over two language systems, maintaining separation between them when speaking to monolinguals, fluently mixing languages when they wish to, and almost never producing words in an unintended language by mistake. Even if rare, unintentional language switches – *cross-language intrusion errors* – provide a unique, rich, and largely unexplored source of evidence about how bilinguals maintain control over language selection. Few investigations of intrusions exist, perhaps because they are difficult to induce in experimental settings. In one study, young bilinguals produced intrusions less than 1%, and aging bilinguals at most 3%, of the time in category generation (Gollan, Sandoval, & Salmon, 2011). The rarity of intrusions in aging bilinguals implies language-specific control mechanisms that remain relatively unaffected by aging-related cognitive decline. However, aging bilinguals with deficits in a nonlinguistic flanker task produced the most intrusions. Thus, language control may be maintained both by language-specific mechanisms, and by domain-general mechanisms that support both linguistic and non-linguistic tasks (Weissberger, Wierenga, Bondi, & Gollan, 2012).

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Two prominent hypotheses about bilingual language control could play a key role in explaining intentional and unintentional language mixing. One view assumes that bilinguals inhibit the dominant language (Green, 1986; 1998) to enable switching to the non-dominant language. Supporting this view, the dominant language exhibits large switch costs in cued language switching (Meuter & Allport, 1999). *Dominance reversal*, in which bilinguals respond more slowly in their dominant than non-dominant language, provides further evidence of inhibition. Reversal has been reported both for cued (e.g., Christoffels, Firk, & Schiller, 2007; Costa & Santesteban, 2004; Verhoef, Roelofs, & Chwilla, 2009) and voluntary language mixing (Gollan & Ferreira, 2009).

Another, mutually compatible asymmetry in bilingual language control is hypothesized by Myers-Scotton (1993; 1997; 2002), who suggested that one language functions as the *Matrix Language* - providing syntactic frames, the majority of words, morphemes and inflections, and dictating word order for mixed-language utterances. Within this view, function words should be retrieved relatively automatically, reducing or preventing intrusion errors. In addition to function words, other grammatical elements (e.g., language specific requirements on word order) would be expected to come from the Matrix language, and mixed language utterances that violate these constraints should be difficult to produce.

Surprisingly from this perspective, Poulisse (1999; Poulisse & Bongaerts, 1994) found that most intrusions involved function word targets (articles, pronouns, conjunctions and editing terms; e.g., “I mean”) for Dutch-English bilinguals in object naming, design description, story retelling, and a short interview. These bilinguals produced intrusions at most 1% of the time, fewer of them when speaking Dutch than English (their late-learned, non-dominant language). Kolers (1966) reported a similar result for proficient French-English bilinguals who read aloud paragraphs that alternated “haphazardly” between languages; bilinguals sometimes inadvertently produced language intrusions—instead of saying the written word, they produced its translation by mistake. Again, most of these errors involved function word targets.

We explored bilingual language control by investigating language dominance and word order effects on intrusion errors for function versus content words using Kolers’ (1966) paradigm. Although different from natural language production, the reading aloud paradigm allows elicitation of connected speech and rapid production of many words, increasing statistical power for observing error patterns on intrusions (normally an infrequent phenomenon).

When bilinguals mix languages voluntarily, we hypothesize they inhibit the dominant language (Gollan & Ferreira, 2009). If similar mechanisms support reading aloud mixed-language passages, intrusion errors in this task might exhibit dominance reversal (i.e., for English-dominant bilinguals English words would slip into Spanish more often than the reverse). We further hypothesized that function words would be relatively immune to intrusion errors when they match the Matrix Language (e.g., English function words would be less likely to slip into Spanish by mistake in paragraphs with English word order, and vice versa). Kolers reported that bilinguals were equally likely to substitute “English to French as from French to English,” but did not report whether intrusions were modulated by target-language word order. However, he tested only a small number of bilinguals ($n=12$), both French-dominant and English-dominant, which could have obscured dominance effects.

Given the apparently consistent vulnerability of function words to intrusion errors across multiple paradigms (Kolers, 1966; Hartsuiker & Declerck, 2009; Poulisse, 1999), we used eye movement data to explore whether this could be attributed to differences in attention

given to accessing and monitoring content versus function words (Poulisse & Bongaerts, 1994). In silent reading, where a person looks (i.e., overt attention) is an indicator of where the person attends (i.e., covert attention; Rayner, 2009). Monolinguals often skip words (Schotter, Angele, & Rayner, 2012), allocating less overt attention to them, and function words are skipped more often than content words (35% versus 15% respectively; e.g., Carpenter & Just, 1983; Rayner, 1998). When reading aloud, the eyes are often ahead of the voice (Buswell, 1922; Inhoff, Solomon, Radach & Seymour, 2011), separating overt and covert attention. In mixed-language paragraphs this could lead to bilinguals to plan production of a word in one language while looking at a word in the other language; increased vulnerability to intrusions in such cases could reveal the role of attention in maintaining language control.

Method

Participants

Thirty-two Spanish-English bilinguals at UCSD participated for course credit. Table 1 shows participant characteristics. Most bilinguals were English-dominant based on picture naming test scores; two exceptions were closely balanced bilinguals.

Materials & Procedure

Bilinguals completed a language-history questionnaire and attempted to name 33 pictures (even items plus one from the Multilingual Naming Test; Gollan, Weissberger, Runnqvist, Montoya, & Cera, 2012). Sixteen paragraphs with 108 words on average ($SD=11$) were selected from short stories published in English and Spanish (see supplemental materials). These were adapted to create two mixed-language versions by 3 Spanish-English bilinguals, matching mixing frequency to the example published by Kolers (1966). Each bilingual read 16 paragraphs, four in each of four conditions (a) English-only, (b) Spanish-only, (c) mixed language with English word order, or (d) mixed language with Spanish word order. Paragraphs were rotated across conditions between subjects with a Latin-square. Paragraph order was randomized uniquely for each bilingual.

Eye movements were recorded via an SR Research Ltd. Eyelink 1000 eye-tracker with a temporal resolution of 500 Hz without head restraint, but monitoring head position. After calibration, eye position error was less than 1° . Bilinguals were seated 60 cm from a 20-inch CRT monitor with 1280×1024 pixel resolution. Although viewing was binocular, only right eye movements were recorded. At the start of the experiment, participants completed a 9-point calibration and validation procedure to allow monitoring of both horizontal and vertical eye movements. At the start of each trial, a black box (65 pixels wide and 85 pixels tall) appeared in the top-left corner of the screen, where the first word would appear. When a fixation was detected in this box it disappeared and was replaced by the paragraph. Paragraphs were presented as black letters on a white background in 32-point Courier New font with 1.7 letters equaling 1° of visual angle. Bilinguals were instructed to read the paragraphs aloud as accurately as possible at a comfortable pace. A bilingual experimenter recorded errors and later checked coding using audio-visual recordings with the audio time-locked to a video of the eye movement record.

Results

Errors were classified as either (a) intrusions (e.g., saying *pero* instead of *but*), (b) partial intrusions (starting to produce an intrusion but self-correcting before producing the error), (c) accent errors (e.g., saying the correct word with the accent of the non-target language), and (d) within-language errors (e.g., saying *such* instead of *much*). All bilinguals produced

at least one intrusion and up to as many as 30. Accent errors (see also Kolers, 1966) were identified as such by two Spanish-English bilingual assistants; none of the bilinguals tested had a strong accent in either language in spontaneous speech. We focus primarily on intrusions and report in separate sections below analyses to consider effects of (a) language mixing, (b) part-of-speech (function versus content), (c) language and (d) word order (English versus Spanish) on production of errors. In a final section, we report (e) analyses of eye movement data to consider if part-of-speech effects were modulated by word-skipping, and by looking at words in the non-target language. Data were analyzed using logistic regressions (Jaeger, 2008) in which b values represent effect size in logit space (see also ANOVAs in supplemental materials).

Factors that Elicited Intrusion Errors

Table 2 shows the number of errors produced in each language in each condition. Bilinguals produced intrusion errors almost exclusively in mixed-language paragraphs—significantly more often than in language-selective paragraphs ($b=9.39$, $SE=1.41$, $z=6.64$, $p<.001$), suggesting that it is unusual for bilinguals to mix languages haphazardly (Sridhar & Sridhar, 1980; Dussias, 2003). However, language-mixing did not increase errors in a generalized way; bilinguals produced *fewer*¹ within-language errors in the mixed-language than language-selective paragraphs, ($b=-1.40$, $SE=.16$, $z=8.86$, $p<.001$). Because our primary goal was to characterize intrusion errors we did not test for an interaction (but see supplemental materials). However, data patterned significantly in opposite directions for the two types of errors (note the sign difference in the b values).

Rows labeled with ‘total’ in Table 3 show that the majority of intrusions involved function (mostly articles, pronouns, prepositions, conjunctions, and quantifiers) rather than content word targets (mostly nouns, some adjectives and verbs; $b=.72$, $SE=.21$, $z=3.41$, $p<.001$). Proper names were excluded because they elicited exclusively accent errors. In contrast, and matching previous observations about monolingual speech errors (Garrett, 1982; Levelt, 1989), within-language errors patterned in the opposite direction, fewer errors with function than content word targets ($b=-.60$, $SE=.15$, $z=4.15$, $p<.001$).

Among content word targets, intrusions were about 5 times more likely to involve cognates² than noncognates (e.g., *familia* → *family* > *amigo* → *friend*; $b=-3.96$, $SE=.76$, $z=5.20$, $p<.001$), but function words trended in the opposite direction. Because we did not manipulate cognate status (only 9% of paragraph words were cognates, excluding proper names) and few function words are Spanish-English cognates, we do not consider these effects in detail but note that if cognates induce intrusions this may involve mechanisms similar to those that cause cognates to trigger intentional language switches on subsequent words (Broersma, 2009; Broersma, Isurin, Bultena, & De Bot, 2009; Kootstra, van Hell, & Dijkstra, submitted).

Do Bilinguals Inhibit the Dominant-language to Achieve Language-Mixing?

Figure 1 shows target language effects collapsed across condition. Demonstrating their English dominance, bilinguals produced significantly more within-language errors when attempting to produce Spanish than English targets ($b=.96$, $SE=.20$, $z=4.87$, $p<.001$). In contrast, and suggesting that bilinguals inhibited English when reading language-mixed paragraphs, intrusions patterned in the opposite direction; bilinguals produced intrusion

¹This difference was not significant after adjusting for opportunities to err in each language (e.g., all words were in English in English-only paragraphs, whereas there were only 60% and 40% English words respectively in English versus Spanish word-order paragraphs)

²The majority of cognates in the paragraphs were not identical across languages (e.g., *family* and *familia*) with few exceptions (e.g., *comparable*), which we classified as produced correctly regardless of accent.

errors significantly *less* often when attempting to produce Spanish than English targets, ($b = -.81$, $SE = .24$, $z = 3.43$, $p < .001$), and the same pattern was observed for accent errors, ($b = -1.25$, $SE = .45$, $z = 2.76$, $p < .01$).

Measures of reading fluency also confirmed the bilinguals' English dominance; total passage reading times were faster for English-only ($M = 31.7$ s, $SD = 5.6$) than Spanish-only paragraphs ($M = 40.3$ s, $SD = 7.5$; $t(31) = 8.78$, $p < .001$), and the difficulty of reading aloud haphazardly language-mixed text (Kollers, 1966); language-selective total passage reading times were faster than language-mixed paragraphs with English word order ($M = 44.1$ s, $SD = 8.9$) and Spanish word order ($M = 45.6$ s, $SD = 8.4$; both $ps < .01$).

Does Word-Order Facilitate Retrieval of Function Words?

Figure 2 illustrates opportunity-to-err adjusted rates of intrusion errors—the proportion of intrusion errors, taking into account how many function or content words there were in each language (English word order paragraphs had about twice as many English function words as Spanish word order paragraphs, and vice versa). We analyzed the incidence of intrusions in language mixed paragraphs as a function of matrix language (English word order, Spanish word order), target language (English, Spanish) and part of speech (function, content). Because intrusions were rare, there were many words for which an error was never observed, leading to difficulties using traditional logistic regressions (i.e., the log odds of 0 is undefined). Thus, we performed a linear regression with subjects and paragraphs (instead of individual words) as crossed random effects with an empirical logit transform (Barr, 2008), using the maximal random effects structure (Barr, Levy, Scheepers, & Tily, 2013). Given the large number of observations, the t distribution approaches the normal distribution, and absolute t -values > 1.96 indicate significance at the .05 level.

Bilinguals produced more intrusions with English than Spanish targets, ($b = -0.24$, $SE = 0.11$, $t = 2.23$), and when targets did not match the matrix language, a significant interaction between matrix language (i.e., word order) and target language ($b = 0.81$, $SE = 0.19$, $t = 4.18$). Analyzing function and content targets separately, mismatch between target language and matrix language was significant for function ($t = 5.43$), but not content words ($t = 1.05$). Thus, there was a three-way interaction between matrix language, target word language, and part of speech ($b = -0.93$, $SE = 0.39$, $t = 2.39$). No other effects were significant ($ts < 1.08$).

Eye Movements Suggest Vulnerability of Function Words to Contextual Distraction

An important question is whether skipping, or fixating on words in the wrong language, can explain part-of-speech effects (i.e., why function words were more vulnerable to intrusions), and reversed language dominance effects. Table 4 shows skipping rates for function and content targets produced as errors and correctly (by different bilinguals). For intrusions, there was no main effect of skipping ($p > .50$), but this null effect was qualified by a marginally significant interaction with part-of-speech ($b = 2.59$, $SE = 1.38$, $z = 1.88$, $p = .06$); bilinguals were significantly more likely to produce an error when they skipped compared to fixated on function ($b = .90$, $SE = .28$, $z = 3.18$, $p < .005$), but not content words ($p > .33$). Within-language errors patterned similarly, no main effect of skipping ($p > .18$), but skipping affected function more than content words (a significant interaction; $b = -2.46$, $SE = 1.24$, $z = 1.98$, $p < .05$). Thus, skipping increased errors both within and across languages, for function but not content word targets, possibly reflecting similar consequences of not allocating overt attention during word identification.

Importantly, skipping alone cannot explain differential part-of-speech effects on the two error types because the majority of intrusion targets were fixated (i.e., not skipped, 84%). Part-of-speech effects on intrusion errors were robust even after excluding all skipped

targets from the analysis ($b=.62$, $z=3.05$, $p<.005$), as were reversed language dominance effects ($b=-.76$, $z=3.09$, $p<.005$). However, part-of-speech effects may be partially explained by increased vulnerability of function word targets to contextual distraction. Whereas bilinguals tended to look directly at content word targets when reading aloud, which prevented errors, they were more likely to not directly fixate function words. Figure 3 illustrates that a larger proportion of function word intrusions occurred when bilinguals looked at a word in the other language when they produced the error, and also that most correct responses were produced when bilinguals were looking directly at target words.

To determine if looking at words in the other language might explain part-of-speech effects, we assessed whether function words outnumbered content words as targets of intrusion errors only when bilinguals looked at words in the wrong language during error production. Indeed, bilinguals were less likely to produce an intrusion, and more likely to produce a correct response, when they looked at a word in the same than a different language ($b=-1.21$, $SE=.34$, $z=3.53$, $p<.001$) and this effect seemed to be driven primarily by function word targets (Table 5). Although there was no interaction with part-of-speech, ($p>.82$; but see ANOVA in supplemental materials) this was likely due to sparse data for content words (because bilinguals often looked directly at content words when they produced them and we excluded these cases from this analysis). For function word targets, bilinguals were significantly more likely to produce an intrusion error when looking at a word in the other language ($b=1.27$, $SE=.27$, $z=4.66$, $p<.001$). In contrast, the model for content word targets failed to converge (due to the problem of insufficient data, mentioned above).

Discussion

The results reported here imply both domain-general and language specific mechanisms of bilingual language control, and reveal reading aloud to be useful for inducing speech errors. Although we observed a large number of language intrusion errors (290; compared with just 18 produced by young bilinguals in Gollan et al., 2011), the rate of errors (about 0.6%) was in line with other tasks (0.4% in Gollan et al., 2011). Reading aloud also elicited many monolingual-like (i.e., within-language; $n=326$) errors, and comparisons of these with intrusions revealed opposite patterns, implying distinct underlying mechanisms.

Bilinguals produced intrusion errors more often (a) in language-mixed paragraphs (b) for words in their dominant language (i.e., intrusions exhibited reversed language dominance), and (c) for function word targets. In contrast, bilinguals produced within-language errors more often (or after adjusting for opportunities to err equally often) (a) in language-selective paragraphs, (b) for words in their non-dominant language, and (c) for content word targets (even though paragraphs had about twice as many function as content words). Looking more closely at intrusion errors, matrix language (word order) facilitated retrieval of the target language, particularly for function word targets. In addition, eye movement data revealed that part-of-speech effects on intrusion errors were partially (but not entirely) explained by absence of overt attention, and distraction caused by looking at words in the non-target language (when bilinguals produced errors with function, but not content word targets).

Reversed language dominance effects imply that bilinguals inhibit the dominant language (Green, 1986; 1998; Misra et al., 2012) when they intend to mix languages (Gollan & Ferreira, 2009). Thus, Spanish intruded into English more often than the reverse, even though our bilinguals were English-dominant. Reversed language dominance has been reported in cued (e.g., Christoffels, et al., 2007; Costa & Santesteban, 2004; Verhoef et al., 2009) and voluntary (Gollan & Ferreira, 2009) language switching paradigms. Dominance reversal both for intrusion and accent-only errors implies that inhibition is applied at both lexical (Phillip & Koch, 2009) and post-lexical processing levels because accent is specified

independently from, and presumably *after*, lexical selection. Such a process might be easier to maintain if bilinguals represent separate phonological inventories for each language (de Bot, 1992). Similar processes might explain how bilinguals can speak one language with the accent of the other (Grosjean, 1982). Consistent with the proposal that accent is specified post-lexically, unlike intrusion errors, accent errors were produced, on average, equally often ($p=.66$) with function ($M=2.6$; $SD=1.4$) and content ($M=2.3$; $SD=2.4$) word targets (or even more often with content than function word targets if counting proper names as content words; $M=1.3$; $SD=1.7$). Poulisse (1999) did not observe reversed dominance effects, perhaps because her bilinguals had lower proficiency level, or because they were not mixing languages intentionally. Another possibility is that the combination of languages tested is critical (English could be more vulnerable to intrusions than Spanish, but see supplemental materials).

A second apparent force that facilitates selection of words in the intended language appears to be syntactic and follows from Myers-Scotton's proposal (1993; 1997; 2002) that grammatical elements, including function words, are retrieved more automatically than content words in mixed language utterances. Automatic retrieval prevents intrusions for words that match the Matrix, but induces errors for words that do not. On this view, grammatical encoding can facilitate lexical selection; for bilinguals, syntactic frames may specify language-specific slots (perhaps analogous to syntactic category constraints; Dell, 1986; Garrett, 1975; Kootstra Van Hell, & Dijkstra, 2010). Although both content and function word targets tended to exhibit fewer intrusions when they matched (versus did not match) the target language word order, the critical interaction was significant for function, but not content word targets. These findings could imply that naturally occurring bilingual intrusions often involve function words because bilinguals temporarily lose top-down control over specification of the matrix language (not just over selection of individual words).

This fits with the observation that intentional language mixing seldom involves production of single function words (Bullock & Toribio, 2009). Muysken (2000) suggested that the restricted distribution of function words in mixed language clauses reflects their grammatical non-equivalence across languages [e.g., differences in word order "*lo quiero comer*" (*it I-want to-eat*) may discourage mixing languages on the clitic, which appears at the end in "*I want to eat it*"]. If non-equivalence discourages bilinguals from mixing on purpose, why doesn't it also prevent them from mixing languages by mistake? Poulisse and Bongaerts (1994) suggested that function words intrude more often because dominant language function words are much higher frequency than their intended non-dominant language equivalents. This explanation doesn't work for our data given that the non-dominant language intruded more often than the dominant language. Poulisse and Bongaerts (1994) also suggested that reduced automaticity of speech in beginning learners leaves little attention to spare for accessing and monitoring function words that convey little meaning. Confirming the role of attention, they reported a greater proportion of content than function word targets were self-corrected, and suggestive of similar processes in our proficient bilinguals, of the 46 partial intrusions (i.e., self-corrections) 43 involved content words and only 3 function word targets.

Thus, part-of-speech effects could motivate an attention based control mechanism – possibly a form-sensitive monitoring process (Levelt, 1989; Slevc & Ferreira, 2006) that checks planned utterances for match with intended target language, and that more easily misses short than long words in the non-target language³. On this view, function words should elicit intrusions more often than expected by chance; consistent with this prediction, 66% of the intrusion errors and 62% of words in the paragraphs were function words (this difference is small; but see larger differences in Poulisse & Bongaerts, 1994). This view also assumes that

language control mechanisms are insensitive to frequency. By contrast, function words were less often targets of within-language errors in the current data, and also in monolingual speech errors (Garrett, 1982; Levelt, 1989). Even though function words comprise the majority of words produced, both in our paragraphs and in spontaneous speech (55–60%, Bell, Brenier, Gregory, Girand, & Jurafsky, 2009; Poulisie & Bongaerts, 1994), they may be less vulnerable to within-language errors because extremely high-frequency words are easier to produce. Eye movement data also supported attention-based explanations of part-of-speech effects. Only function word targets were vulnerable to contextual distraction – being targets of intrusion errors more often when bilinguals fixated a word in the other (as opposed to the same) language. One strategy bilinguals seemed to employ to avoid making errors was to look directly at the target words when they were producing them (see Figure 3).

A potential limitation was our use of reading aloud to elicit errors. Language selection in reading aloud will necessarily begin with word identification, and in language-mixed paragraphs, determination of language membership (Kolers, 1966). But we hypothesize that after this point language selection and control will primarily be influenced by processes that elicit language control in normal speech. Support for this hypothesis is that fact that the majority of intrusion errors observed (61%; 177/290) involved noncognates, which could not possibly reflect misidentification (e.g., *pero* does not share any letters with its translation *but*). Also relevant was our replication of previously reported patterns both in terms of the predominance of function word targets in intrusions (Poulisie, 1999; Hartsuiker & Declerck, 2009), and the relatively lower rate of within-language errors with function word targets (Garrett, 1982; Levelt, 1989).

The proposal of multiple bilingual language control mechanisms including inhibition at both lexical and sub-lexical levels, grammatical encoding constraints, and monitoring, resembles proposals of multiple monitors in monolingual language production (for review see Hartsuiker, Bastiaanse, Postma, & Wijnen, 2005), and might explain the rarity of language selection failures. However, although we observed more intrusions than within-language errors in haphazardly mixed-language paragraphs, it remains an open question if intrusions in normal bilingual speech should be classified as frequent or rare. If intrusions are produced less frequently than within-language *semantic whole-word* substitution errors, this would provide strong support for models that restrict activation of intended targets via language tags (e.g., Green, 1998; perhaps analogous to syntactic constraints on lexical selection in monolingual production; Dell, Oppenheim & Kittredge, 2008). Further investigation of bilingual speech errors – and how they differ from semantic substitution errors within-language – should lead to further insights about bilingual language control, and language production more generally.

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³A similar process might explain why most content word targets that elicited intrusion errors were cognates (see Table 3), or cognate effects might instead resemble mixed-error effects in monolingual speech errors (e.g., Dell, 1986; Nozari, Dell, & Schwartz, 2011; Rapp & Goldrick, 2000).

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Fig. 1. The average number of errors of each type produced in each target language (collapsed across condition). Error bars show standard errors by language.

Fig. 2.

The average number of intrusion errors for content or function words in English versus Spanish word order paragraphs in each language divided by the number of opportunities to err for each target type. Error bars show standard errors by English or Spanish word order.

Fig. 3.

For each type of target word (content or function) that was produced as a cross-language intrusion error, the percent of cases in which bilinguals were looking directly at the target word, at words in the same language, or at words in a different language (on left), along with the relevant control trials (on right) in which other bilinguals produced those same targets correctly.

Table 1**Bilingual Participant Characteristics**

	<i><u>M</u></i>	<i><u>SD</u></i>
Age (years)	20.5	2.0
Daily use of English (%)	81.5	14.7
Daily use of English during childhood (%)	58.1	17.2
Age of exposure to English (years)	3.7	3.0
Age of exposure to Spanish (years)	0.7	1.4
English picture naming score ^a	29.4	1.8
Spanish picture naming score ^a	23.6	4.8
Years lived in Spanish speaking country	1.2	2.7
How often say a word in the other language without meaning to ^b	2.3	0.9
Self-rated English proficiency ^c		
Spoken	6.4	1.2
Reading	6.3	1.0
Writing	6.3	1.0
Listening	6.5	1.1
Self-rated Spanish proficiency ^c		
Spoken	5.9	1.4
Reading	5.8	0.9
Writing	5.3	1.0
Listening	6.5	0.9

^aTotal possible score = 33.

^bRatings on a scale from 1 (never), 2 (very infrequently), 3 (occasionally), to 6 (constantly).

^cProficiency-level ratings on a scale from 1 (little to no knowledge) to 7 (like a native speaker).

Table 2

Total number of errors of each type produced in each language in each condition

Language of Target word	error type	Language of Written Paragraph				total
		language-selective		mixed language		
		English only	Spanish only	English word order	Spanish word order	
English	intrusion	1	-- <i>a</i>	104	97	202
	partial intrusion	1	-- <i>a</i>	14	25	40
	accent	15	-- <i>a</i>	75	58	148
	within-language	43	-- <i>a</i>	33	27	103
Spanish	intrusion	-- <i>a</i>	2	50	36	88
	partial intrusion	-- <i>a</i>	0	4	2	6
	accent	-- <i>a</i>	2	15	36	53
	within-language	-- <i>a</i>	113	54	56	223

^aThere were no opportunities to err in these cells (e.g., Paragraphs written in Spanish presented no English target words on which speakers could produce a within-language error).

Table 3

Average (and standard deviation) number of errors of each type produced with content or function word targets that were cognates or noncognates (collapsed across paragraph type and language)

	content word targets					
	intrusion		partial intrusion		accent	
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
cognate	2.6	1.7	1.2	1.4	1.0	1.3
noncognate	0.5	1.0	0.2	0.5	1.3	1.7
proper noun	0	--	0	--	1.3	1.7
<i>total</i> ^a	3.1	2.3	1.3	1.6	3.7	2.8
	function word targets					
	intrusion		partial intrusion		within-language	
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
cognate	1.0	0.9	0.0	0.0	0.1	0.2
noncognate	5.0	4.2	0.1	0.3	2.5	1.3
<i>total</i>	6.0	4.5	0.1	0.3	2.6	1.4

^aTotal means were calculated separately (not simply sums of column means).

Table 4

Average (and standard deviation) percent of targets that were skipped during reading aloud for intrusion or within-language errors versus controls, broken down by part-of-speech (and collapsed across condition).

error type	target type	target word produced			
		as an error		correctly	
		<u>M</u>	<u>SD</u>	<u>M</u>	<u>SD</u>
intrusion	content	2.4	9.9	5.4	6.9
	function	22.2	26.6	12.4	9.8
within-language	content	2.0	6.2	1.5	7.0
	function	19.8	32.4	2.6	7.4

Table 5

Average (and standard deviation) number of targets that were content or function words produced as intrusion errors when bilinguals were looking directly at the target word, at a different word in the same language, or at a different word in the other language

<u>Intrusion produced when looking at:</u>	<u>content</u>		<u>function</u>	
	<u><i>M</i></u>	<u><i>SD</i></u>	<u><i>M</i></u>	<u><i>SD</i></u>
target word	2.5	2.2	2.3	2.2
non-target word in the same language	0.2	0.4	1.4	1.6
non-target word in the other language	0.3	0.5	2.3	2.1