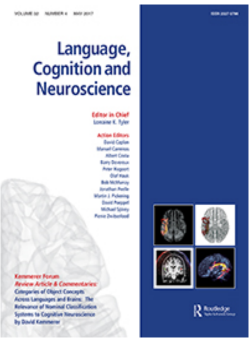

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Bilingual language switching costs in auditory comprehension

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ABSTRACT
Previous research on bilingual language switching and lexical access has demonstrated a consistent reaction time cost associated with producing a switched token. While some studies have shown these costs to be asymmetrical, with bilinguals evidencing a greater delay when producing switches into their dominant language relative to the non-dominant language, others have shown symmetrical costs, depending on individual (e.g. proficiency) and contextual (e.g. language mode) factors. The current study, employing an eye-tracking paradigm, extends this line of research by examining the potential for switch costs during auditory comprehension. Paralleling previous production-oriented research, results of the current study demonstrate flexible switch costs during auditory comprehension. Switch costs were asymmetrical in monolingual mode, with greater costs incurred when switching into the dominant language, and uniformly absent in bilingual mode. Results are discussed with respect to bilingual language selection mechanisms in both production and comprehension.

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Bilingualism; language switching; comprehension; lexical access

Introduction

As bilinguals engage in communication, they are consistently tasked with separating and selectively accessing each of their two languages. While separation and selection may seem like a complex task, particularly in light of the partially or fully overlapping brain regions dedicated to each language (Chee, Tan, & Thiel, 1999; Hernandez, Dapretto, Mazziotta, & Bookheimer, 2001; Illes et al., 1999), a number of researchers have noted the extreme infrequency with which bilinguals produce cross-linguistic speech errors (e.g. Poulisse, 1999). While unintentional switches are rare, intentional alternation between a bilingual's two languages, known as code switching, is common in many bilingual communities for a range of pragmatic purposes (Zentella, 1997). Although the production of code switches in connected speech occurs nearly "seamlessly" (Olson, 2013), recent psycholinguistic research, drawing partially on cued language switching paradigms (e.g. Meuter & Allport, 1999), has demonstrated that producing language switches incurs a small temporal cost, generally in the range of tens of milliseconds. While early studies suggested that this switch cost is greater when bilinguals are switching into a more dominant language relative to their non-dominant language (e.g. Meuter & Allport, 1999), more recent work has shown that switch cost symmetry or asymmetry is dependent on individual factors, such as proficiency (e.g. Costa & Santesteban, 2004), and contextual factors, such as language mode (e.g. Olson, 2016).

While robust evidence for this switch cost has contributed significantly to theories regarding the cognitive mechanisms involved in language switching and language selection (e.g. for Inhibitory Control, see Green, 1986, 1998; Kroll & Stewart, 1994), it is worth nothing that the majority of this work has relied on production-oriented experimental paradigms. However, just as bilinguals may produce language switches in everyday conversation, they must also comprehend language switches. As such, any comprehensive theory for language selection and language switching must account for both speech production and comprehension.

Building on previous research, the present study employs an eye-tracking paradigm to examine the time course of comprehension of language switching. Moreover, this study investigates potential variability in the time course of comprehension, driven by both individual and contextual factors. The results are discussed with respect to language selection and switching mechanisms in both production and comprehension.

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Literature review

Language switching and production

In naturalistic speech, bilinguals often alternate between their two languages, a process known as *code switching*, for a number of pragmatic and communicative functions (e.g. Gumperz, 1982). While code switching has been the subject of a large body of research, focused primarily on the syntactic constraints (for review, see Macswan, 2013), pragmatic functions (e.g. Zentella, 1997), and to a lesser extent, the phonetic outcomes (e.g. Bullock, Toribio, González, & Dalola, 2006), code switching may not be ideal for the purpose of investigating lexical access in speech production (Olson, 2013). Specifically, connected speech is pre-planned, with "buffering" times of up to 1000 ms (Griffin & Bock, 2000), and as such this pre-planning may serve to mask switching effects at the point of switch. The notion that code switches are pre-planned is further supported by Bullock et al. (2006) who found modulation at the phonetic level of words *preceding* a code switch. In light of these restrictions, to examine lexical access in bilingual populations, researchers have turned to psycholinguistic paradigms involving *language switching*, changes in language, often cued or triggered, that are not necessarily constrained by connected speech.

In one of the earliest studies to draw on the cued language switching paradigm, Meuter and Allport (1999) investigated the time course of lexical access and language switching through a digit naming task. In this task, bilinguals were asked to name a given digit in their first (L1) or second (L2) language, depending on the background colour of the visually presented numeral. Their results demonstrated that participants were significantly slower when naming a digit in a switch trial (i.e. when preceded by a digit from the opposite language) relative to a stay trial (i.e. when preceded by a digit from the same language). This reaction time difference between switch and non-switch trials is referred to as the *switch cost*, and was taken to be analogous to the time cost incurred by switching between the two languages. Moreover, this study revealed an asymmetry in switch costs, such that bilinguals were significantly slower when switching into their dominant language relative to their non-dominant language. These costs have been shown to apply to the language as a whole, rather than a response sub-set (Philipp & Koch, 2009), and are partially driven by the recency of activation of the target language (Philipp, Gade, & Koch, 2007). Subsequent work has examined the relative variability in switch costs, with switch cost asymmetry or symmetry dependent on a number of factors.

A number of studies have sought to determine if switch costs, and more specifically the asymmetries in switch costs for dominant and non-dominant languages, are evidenced in a variety of bilingual and multilingual populations. Costa and Santesteban (2004), for example, examined switch costs during a cued picture naming task in late bilinguals, early balanced bilinguals, and trilinguals with a significantly weaker third language (L3). Results for the late, L1-dominant bilinguals illustrated the expected asymmetrical switch costs, while the early balanced bilinguals demonstrated symmetrical switch costs. Moreover, trilingual participants, equally proficient in the L1 and L2, and significantly less proficient in the L3, demonstrated symmetrical switching costs when switching into the L3. While these results suggest that balanced bilinguals may demonstrate symmetrical switching costs, subsequent research showed that highly proficient bilinguals may produce asymmetrical switch costs when switching between an L3 and weaker L4 (Costa, Santesteban, & Ivanova, 2006; Linck, Schwieter, & Sunderman, 2012). Building on these results, Schwieter and Sunderman (2008) investigated the possibility that proficiency, operationalised as "lexical robustness" (e.g. Gollan, Montoya, & Werner, 2002), may impact switch costs. Results from this cued picture naming study confirmed that lexical robustness may play a key role in bilingual switch costs. Specifically, there was a positive correlation between L2 lexical robustness and the degree of switch cost symmetry, such that participants with greater lexical robustness in their non-dominant language demonstrated more symmetrical switch costs. Importantly, these results have been linked to proficiency rather than age of acquisition (AoA; Calabria, Hernández, Branzi, & Costa, 2012; Costa et al., 2006).

While the examination of individual factors, including proficiency, demonstrated variability in switch costs between different groups and individuals, more recent examinations of contextual factors have shown that switch costs may vary within a given individual. Olson (2016), for example, examined the role of language mode on switch cost (a)symmetry. Broadly, *language mode* is defined as the position of a given individual on a communicative continuum from monolingual operation in Language A to monolingual operation in Language B, including varying degrees of bilingual operation (e.g. Grosjean, 2001, 2008).[1] In a cued picture naming study, Olson (2016) manipulated the language mode of L1 dominant Spanish–English bilinguals over three different experimental sessions by varying the number of tokens drawn from each language (i.e. 95% English–5% Spanish vs. 50% English–50% Spanish vs.

5% English–95% Spanish). Results demonstrated that, in more monolingual contexts, participants produced the expected asymmetrical switch costs. In contrast, the same participants produced symmetrical switch costs in bilingual or balanced contexts. These results, in line with Green and Abutalebi's (2013) proposal for adaptive control, highlight the variable nature of switch costs, with variability being driven by external factors (i.e. language mode). Further support for contextually driven variability in switch cost (a)symmetry can be seen in the symmetrical switch costs found in a voluntary, non-cued switching paradigm (Gollan & Ferreira, 2009) and cued switching paradigms with longer inter-stimulus intervals (Verhoef, Roelofs, & Chwilla, 2009), as well as reduced switch costs for cognate tokens (Declerck, Koch, & Phillipp, 2012).

Results from production-oriented language switching paradigms, both symmetrical and asymmetrical, have been crucial for developing a framework for the cognitive mechanisms responsible for language selection. Among the first to consider and incorporate such findings is the Inhibitory Control Model (ICM) (Green, 1986, 1998). Generally, the ICM posits that language selection is driven by inhibitory mechanisms, such that inhibition is applied to lexical entries of the competing language(s), resulting in the accurate selection of the target item from the target language. As such, asymmetrical switch costs result directly from asymmetrical inhibition applied to the two competing languages, with the dominant language subject to greater levels of inhibition. In line with this original proposal and considering contextually driven variability in switch costs, Olson (2016) suggests that inhibition may be considered to be gradient in nature, with the level of inhibition modulated by contextual factors.[2]

This inhibitory framework has found support from a number of different methodologies beyond the cued switching paradigm, including pathological switching (Alberta & Obler, 1978; Fabbro, Skrap, & Aglioti, 2000; Paradis, 1977; Paradis, Goldblum, & Abidi, 1982), event-related potentials (ERP) (Guo, Liu, Misra, & Kroll, 2011; Jackson, Swainson, Cunnington, & Jackson, 2001; for differences in behavioural and ERP, see Christoffels, Firk, & Schiller, 2007) and neuroimaging (Abutalebi et al., 2007; Hernandez, 2009; Hernandez et al., 2001; Price, Green, & von Studnitz, 1999; Wang, Xue, Chen, Xue, & Dong, 2007). Moreover, a number of authors have noted clear parallels with task switching (see Kiesel et al., 2010; Koch, Gade, Schuch, & Philipp, 2010; Monsell, 2003), although results have been marginal for some studies (e.g. Calabria et al., 2012; Klecha, 2013; Prior & Gollan, 2013). In addition, it has been argued that the mechanisms for language selection may not be language specific, but rely (at least partially) on broader cognitive control mechanisms (e.g. Meuter & Allport, 1999). This proposal has found support from recent neuro-imaging paradigms showing similar neural networks involved in both language control and non-linguistic task control (e.g. Abutalebi et al., 2013; Bialystok, Craik, Green, & Gollan, 2009; De Baene, Duyck, Brass, & Carreiras, 2015; Garbin et al., 2010; Weissberger, Gollan, Bondi, Clark, & Wierenga, 2015).

While the cued language switching paradigm, along with the other paradigms discussed above, has been crucial for the development of theories regarding the cognitive mechanisms for bilingual language selection and switching, this research has focused primarily on bilingual language production. Yet, production remains only half of the communicative process, and in naturalistic speech bilinguals must also comprehend language alternations. As such, any cogent theory of bilingual language selection must address both production and comprehension.

Language switching and comprehension

In an early proposal regarding language switching mechanisms, Macnamara and Kushnir (1971) amended the prior depiction of a single, categorical "language switch" (Penfield & Roberts, 1959) to include two separate language switches: input and output. Their proposal drew on the experience of simultaneous translation, in which bilinguals were able to comprehend Language A while simultaneously producing Language B. This proposal was among the first to recognise the fact that, while bilinguals are certainly tasked with language selection during production, they must also effectively separate and select a given language during comprehension.

In their seminal work addressing bilingual language comprehension, albeit comprehension of *non-switched* speech, Spivey and Marian (1999) demonstrated a degree of cross-linguistic activation during bilingual spoken word comprehension. Building on previous research in monolingual speakers that showed co-activation of phonologically related competitor tokens (e.g. Tanenhaus, Spivey-Knowlton, Eberhard, & Sedivy, 1995), Spivey and Marian (1999) employed a similar eye-tracking paradigm with bilingual listeners. Specifically, Russian–English bilinguals listened to auditory stimuli (i.e. object names) and were presented with a set of objects in a visual display. Upon hearing the target word (e.g. *marker*), bilinguals fixated on both the target object (e.g. marker), as well as an object with a phonologically related name in the opposite language (e.g. *marka* "stamp"). Subsequent work on a number of language pairings has widely confirmed parallel activation during bilingual language comprehension of non-switched speech (for Dutch–English Weber & Cutler, 2004; French–English Weber & Paris, 2004; Japanese–English Cutler, Weber, & Otake, 2006; Spanish–English Canseco-Gonzalez et al., 2010), and some have suggested that such activation is driven, in part, by bottom up-activation from fine-grained acoustic information (Ju & Luce, 2004).

In attempting to better understand the nature of this parallel activation, a number of studies have demonstrated that such activation is not static, and the degree of parallel activation can be modulated by both individual and contextual factors. For example, Canseco-Gonzalez et al. (2010) demonstrated an effect of AoA, such that stronger activation of the non-target language competitors were found for subjects who acquired the non-target language as an L1. Worth noting, late bilingual participants in this study expressed a daily use preference for their L1, which may imply a link between proficiency and AoA (for further support for the role of proficiency, see Blumenfeld & Marian, 2007; Jared & Kroll, 2001). Moreover, parallel activation was also impacted by language mode, with monolingual mode facilitating faster recognition of target items relative to bilingual mode (Canseco-Gonzalez et al., 2010), although parallel activation is not fully eliminated, even in monolingual mode (Marian & Spivey, 2003). Similar support for the modulation of the degree of parallel activation can be seen in a series of go/no-go studies involving cross-linguistic homophones (for review, see Dijkstra, 2005), with reaction time delays present for cross-linguistic homophones only when stimuli were drawn from both languages (Dijkstra, de Bruijn, Schriefers, & ten Brinke, 2000; Dijkstra, Van Jaarsveld, & ten Brinke, 1998). Similarly, parallel activation also seems to be facilitated, or target recognition slowed, when targets are cross-linguistic cognates (Blumenfeld & Marian, 2007), although this effect may be mitigated by highly restrictive semantic constraints (Schwartz & Kroll, 2006).

While a wide range of research on bilingualism has addressed the production of language switches and the comprehension of non-switched speech, the comprehension of language switches has remained relatively less studied (Linck, Hoshino, & Kroll, 2008; Litcofsky, Tanner, & van Hell, 2015) and has relied heavily on reading paradigms and visual word recognition as opposed to auditory comprehension. Within reading research, for example, there is again support for a cost associated with language switching, with bilinguals being slower to read mixed (sentential) stimuli than unilingual stimuli (Dalyrmple-Alford, 1985; Macnamara & Kushnir, 1971). Moreover, bilinguals evidence ERPs indicative of processing unexpected events when reading code-switched stimuli (Moreno, Federmeier, & Kutas, 2002). Within visual word recognition, bilinguals have been shown to be slower to perform lexical decision tasks for switched targets (Grainger & Beauvillian, 1987; for auditorily presented lexical decision task, see Soares & Grosjean, 1984) and slower to respond to stimuli with opposite language primes (Grainger & Beauvillain, 1988; Grainger & O'Regan, 1992).

With respect to the role of proficiency, there is mixed evidence for differential costs during switching for orthographically presented stimuli based on proficiency. For example, Macizo, Bajo, and Paolieri (2012, Experiment 1) found asymmetrical reaction time costs during a read-aloud naming paradigm, with bilinguals slower to read a switch into the L1 relative to the L2. However, this effect was not present for silent semantic judgements (Macizo et al., 2012, Experiments 2 and 3) or phonological judgements of orthographically presented stimuli (Hosada, Hanakawa, Nariai, Ohno, & Honda, 2012). Also worth noting, while Hosada et al. (2012) did not show different switch costs in the L1 and L2 in terms of reaction times, there was an asymmetry found in brain activity associated with language switching during phonological judgements.

Again, switch costs during comprehension may be flexible. For example, in a visual word, lexical decision task, switch costs were mitigated by the presence of language-specific orthographic cues (for visual word lexical decision, see Grainger & Beauvillian, 1987; Orfanidou & Sumner, 2005; although see Thomas & Allport, 2000). From a grammatical perspective, Dussias (1997) found longer reading times for switches occurring between different grammatical categories (e.g. noun phrases relative to switches between a determiner and noun) (see also Dussias, 2001, 2003). Moreover, employing a visual world eye-tracking paradigm, Valdés Kroff (2012) demonstrated that (Spanish–English) bilinguals make use of the grammatical gender marking of a determiner to predict the following token, with greater delays to comprehension following a cross-linguistic grammatical gender mismatch (i.e. *la galleta* (fem.–fem.) vs. *la* juice (fem.–masc.)).

While the findings of parallel activation, coupled with the delays seen in the comprehension of written stimuli and during lexical decision tasks, suggest a possible reaction time delay associated with language switching, little research has investigated the time course of language comprehension during auditorily presented connected speech.

Research questions

Taken as a whole, previous research in bilingual language production has demonstrated a small, but consistent, reaction time cost associated with switching languages. Moreover, these costs have been shown to be variable, with either asymmetrical switch costs, such that bilinguals evidence a greater cost when switching into their dominant language, or symmetrical switch costs, depending on both individual (i.e. language dominance) and contextual (i.e. language mode) factors. Given these findings, coupled with the consistent finding of cross-linguistic activation in bilingual perception and switch costs seen in the processing of visually presented language switches, the current study seeks to investigate the potential for language switching costs during auditory comprehension of bilingual speech.

To that end, three specific research questions are addressed: (1) Do bilingual listeners demonstrate language switching costs during auditory comprehension? (2) If language switching costs are present, are such costs symmetrical or asymmetrical with respect to language dominance? and (3) If present, are language switching costs modulated by language mode?

Methodology

To investigate the time course of the comprehension of language switches, a visual world, eye-tracking paradigm was conducted with two groups of Spanish–English bilinguals. Drawing on previous research, participant eye movements are taken as indicative of an implicit and (nearly) online measure of auditory language comprehension (Tanenhaus & Trueswell, 2006). Broadly, the visual world paradigm consisted of the auditory presentation of a contextualising utterance, containing either a switched or non-switched target token, and accompanied by a time-locked visual display of an image corresponding to the target token and three competitor images. Reaction times were measured as the temporal delay between the onset of the auditory target token and the first fixation to the corresponding target image.

Participants

A total of 25 Spanish–English bilinguals participated in the eye-tracking paradigm. Participants were recruited at a large, public, Southern US university, and received a stipend for their participation. All participants reported normal speech and hearing, and normal (or corrected to normal) vision. To assess their language profiles, participants completed a language background questionnaire addressing AoA, language proficiency, language use, and language attitudes (Birdsong, Gertken, & Amengual, 2012). Such self-ratings have been shown to be reliable indicators of linguistic performance in both monolingual and bilingual populations (Chincotta & Underwood, 1998; Flege, Mackay, & Piske, 2002; Flege, Yeni-Komshian, & Liu, 1999; Jia, Aaronson, & Wu, 2002). To provide a balanced experimental approach, participants included both English-dominant ($n = 14$) and Spanish-dominant ($n = 11$) participants. With respect to oral proficiency (0 = not well at all, 6 = very well), consisting of both speaking and listening, the English-dominant group self-rated higher in English ($M = 6$, SD = 0) than Spanish ($M = 4.7$, SD = 0.82), a difference confirmed by statistical analysis (pairwise t-test: $t(27) = 6.72$, $p > .001$, $d = 2.24$). Conversely, the Spanish-dominant group self-rated as more proficient in Spanish ($M = 5.9$, SD = 0.26) than English ($M = 5.4$, SD = 0.95) (pairwise t-test: $t(21) = -2.7$, $p = .01$, $d = .72$). Moreover, English-dominant participants acquired English from birth and Spanish later in life (AoA: $M = 12.8$, SD = 3.23) and Spanish-dominant subjects acquired Spanish from birth and English later in life (AoA: $M = 8.0$, SD = 3.38). As seen in Table 1, similar patterns were found for language use and language attitudes, with English-dominant participants favouring English and Spanish-dominant participants favouring Spanish. As such, all participants are considered to be L1-dominant and highly proficient in both languages. For full results from the language background questionnaire, see Appendix 1.

Table 1. Participant language background information.

	Age of acquisition		Proficiency[a]	
	English *M* (SD)	Spanish *M* (SD)	English *M* (SD)	Spanish *M* (SD)
English-dominant	0.0 (0)	12.8 (3.2)	6.0 (0)	4.7 (.8)
Spanish-dominant	8.0 (3.4)	0.0 (0)	5.4 (.95)	5.9 (.3)
	Daily use[b]		**Language attitudes[c]**	
	English *M* (SD)	Spanish *M* (SD)	English *M* (SD)	Spanish *M* (SD)
English-dominant	88.2 (8.8)	11.2 (9.1)	5.8 (0.4)	4.4 (1.2)
Spanish-dominant	54.5 (17.5)	45.3 (17.7)	4.5 (1.1)	5.7 (0.5)

[a]Likert scale 0–6 (0 = not well at all, 6 = very well).
[b]Percentage of time spent speaking a given language.
[c]Composite score for four language attitude questions. Likert Scale 0–6 (0 = highly unfavourable attitude, 6 = highly favourable attitude).

Stimuli

To investigate the role of language switching on the time course of comprehension, two token types were included: stay and switch. Stay tokens are those preceded by the same language and switch tokens are preceded by the opposite language. To investigate the role of language dominance, target tokens were presented in English or Spanish. Lastly, to investigate the role of language mode, utterances were presented in blocks of either monolingual mode, in which the majority of lexical items were drawn from a single language, or bilingual mode, in which both languages were represented with similar frequency.[3] There were a total of eight resulting stimuli conditions (two token types × two target languages × two language modes). Example (1) illustrates the resulting conditions for the English target token *spider*. Parallel conditions were created for the Spanish token *araña*, available in Appendix 2. The target tokens, contextualising utterances, and corresponding audio and visual stimuli are detailed below.

(1) a. Monolingual (English) mode – stay
The teacher sang a song about spiders for her class.

b. Monolingual (Spanish) mode – switch
El chico dijo que quiere ver spiders cuando anda en el bosque.
"The boy said that he wants to see spiders when he walks in the forest."

c. Bilingual mode – stay
Cuando era pequeña, mi hermana loved spiders and other bugs.
"When she was little, my sister loved spiders and other bugs."

d. Bilingual Mode- Switch
She closed her eyes porque no quería ver spiders y otros bichos.
"She closed her eyes because she didn't want to see spiders and other bugs."

Target tokens

Target tokens consisted of 33 nonambiguous objects, represented by black-and-white line drawings (Snodgrass & Vanderwart, 1980). All target names were controlled for length, frequency, cognate status, initial phoneme feature overlap, and non-loanword status (see norming Loanword Norming Study below). Controlling for target length, target names had a similar number of phonemes in both English ($M = 4.18$, $SD = 1.09$) and Spanish ($M = 4.27$, $SD = 0.98$), and a pairwise t-test revealed no difference in length between targets in the two languages ($t(32) = -0.571$, $p = .572$, $d = -.09$). All target tokens are considered to be high frequency lexical items, among the top 12,000 most common words in both English ($M = 3079.4$, $SD = 2742.8$) and Spanish ($M = 3397.6$, $SD = 2753.4$) (for English: Davies & Gardner, 2010; for Spanish: Davies, 2005). Again, statistical analysis revealed no difference in frequency rank between target names in the two languages ($t(32) = -0.711$, $p = .482$, $d = -.12$). Target names are also considered to be non-cognate, with the opposite language counterpart lacking substantial overlap in orthography and phonology (e.g. de Groot, 1992), as previous research has shown faster lexical access for cognate items (Costa, Caramazza, & Sebastian-Galles, 2000; de Groot, Borgwaldt, Bos, & Van Den Eijnden, 2002; Schwartz & Kroll, 2006). Moreover, as the initial phonemes may be particularly relevant for this task, English tokens and their Spanish translations were limited to a maximum overlap of a single phonetic feature (i.e. place of articulation, manner of articulation, or voicing). For example, while the initial phoneme of an English token and its Spanish counterpart may share a manner of articulation (e.g. occlusive for the pair *dog*–*perro*), they do not share place of articulation or voicing features. Table 2 illustrates sample target tokens and their respective features.

Each target token was repeated four times in each language, corresponding to the four different contexts (monolingual non-switched, monolingual switched, bilingual non-switched, bilingual switched).

Thirty-three additional filler images were used, corresponding to non-cognate filler tokens in English and Spanish. Each image, both targets and fillers, was presented 32 times, 8 times as the target image and 24 times as a distractor.

Loanword norming study

To ensure that all target tokens were clearly drawn from the intended language, as opposed to potential *loanwords* or *borrowings* adopted from one language into the other (e.g. Poplack & Sankoff, 1984), a loanword norming study was conducted. A total of 10 Spanish–English bilinguals, different from those who participated in the main study, participated in the loanword norming study. Five participants were English-dominant, self-rating as more proficient in English ($M = 6.0$, $SD = 0.0$) than Spanish ($M = 4.9$, $SD = 0.2$), and having learned English from birth and Spanish (AoA: $M = 13.8$, $SD = 0.5$) later in life. The remaining five participants were Spanish-dominant, self-rating higher in Spanish ($M = 6.0$, $SD = 0.0$) than English ($M = 5.1$, $SD = 0.6$), and having learned Spanish from birth and English (AoA: $M = 11.4$, $SD = 6.6$) later in life.

Participants were provided with a list of orthographically represented words ($N = 99$), including the target tokens in English ($n = 33$), target tokens in Spanish ($n = 33$) and fillers ($n = 33$), and rated each item via a 7-point Likert scale for how English or Spanish-like they considered each token (0 = only English, 6 = only Spanish). The filler tokens were chosen to be potentially acceptable in both English and Spanish, and consisted of cognates (e.g. *doctor*) and generally accepted loanwords adopted from English into Spanish (e.g. *hobby*) or Spanish into English (e.g. *coyote*).

Table 2. Sample target tokens.

Image	English name	English phonetic transcription	English frequency rank	Spanish name	Spanish phonetic transcription	Spanish frequency rank
	Dog	/dɔg/	753	perro	/pero/	1180
	Bear	/bɛɹ/	1624	oso	/oso/	3598
	Spider	/spaɪdɹ/	5619	araña	/araɲa/	4681

Results of the loanword norming study illustrate that the English target tokens were rated as being strongly English-like ($M = 0.3$, SD = 1.1), while the Spanish target tokens were considered to be strongly Spanish-like ($M = 5.5$, SD = 1.3). The filler tokens, not included in the main experiment, were generally rated as potentially acceptable in both English and Spanish ($M = 3.3$, SD = 1.5). Statistical analysis (ANOVA) revealed a significant difference in acceptability ratings by token type (English, Spanish, filler) ($F(2, 987) = 1287$, MSE = 1.76, $p < .001$, $\eta_p^2 = .773$). Planned pair-wise comparisons (TukeyHSD) revealed significant differences between each of the three types of tokens. Namely, the English target tokens were significantly different from the Spanish target tokens (diff. = −5.22, $p < .001$, $d = -4.29$). Moreover, both groups of target tokens were shown to be significantly different from the filler tokens (English: diff. = −3.02, $p < .001$, $d = -2.25$; Spanish diff. = 2.20, $p < .001$, $d = 1.56$). As such, the target tokens for the main experiment are considered to be representative of the intended language (English or Spanish), as opposed to generally accepted loan words.

Contextualising utterances and language mode blocking

All target tokens were included in contextualising utterances, allowing for the control of the main factors: token type (stay vs. switch) and language mode (monolingual vs. bilingual). There were four resulting conditions (Example 1) for each target language, English and Spanish. Moreover, contextualising utterances were used to control for the semantic predictability of the target token (see Semantic Predictability Norming Study below).

Contextualising utterances were matched for the number of lexical items across all eight conditions ($M = 10.37$, SD = 1.74), and a univariate repeated measures ANOVA by token illustrated no significant difference in the number of lexical items per condition ($F(7, 248) = 0.701$, MSE = 3.06, $p = .671$, $\eta_p^2 = .019$). In addition, speech rate across the eight conditions was analysed and the words per minute were calculated for each utterance by dividing the number of words in the utterance by the utterance duration ($M = 235.7$, SD = 34.4). A univariate repeated measures ANOVA by token confirmed similar speech rates across the conditions ($F(7, 248) = 0.875$, MSE = 1079.9, $p = .527$, $\eta_p^2 = .024$).

Broadly, language mode was operationalised as the relative number of words drawn from each paradigm in a given block. As such, stimuli were presented in three blocks: monolingual English, monolingual Spanish, and bilingual. In the monolingual mode conditions, all non-target lexical items in each contextualising utterance were drawn from a single language. The monolingual English block consisted of monolingual contextualising utterances with either: (a) non-switched English target tokens ($n = 33$), (b) switched Spanish target tokens ($n = 33$) or (c) non-switched English filler tokens ($n = 110$). As such, in the monolingual English block, a total of 18.5% of contextualising utterances contained a switched token. Approximately 2% of all lexical items in the monolingual English block were Spanish items. Likewise, the Spanish monolingual block consisted of monolingual contextualising utterances with either Spanish target tokens, English target tokens, or Spanish filler tokens. Filler utterances were included to: (a) create the appropriate ratio of the two languages for a given language mode (e.g. monolingual English mode = 98% English – 2% Spanish); (b) maintain a similar number of utterances in each of the blocks (i.e. 176); (c) and allow for each image to be presented 8 times as a target and 24 times as a distractor.

In the bilingual mode, contextualising utterances consisted of approximately half of all lexical items in English ($M = 5.18$, SD = 2.01) and half in Spanish ($M = 5.20$, SD = 2.08). A paired t-test comparing the number of words from each language showed that there was no significant difference in the number of English and Spanish lexical items ($t(131) = -0.071$, $p = .944$, $d = -.010$) in utterances in the bilingual conditions. The bilingual block consisted of bilingual contextualising utterances, with either: (a) switched English targets ($n = 33$), (b) non-switched English targets ($n = 33$), (c) switched Spanish targets ($n = 33$), (d) non-switched Spanish targets ($n = 33$), or (e) fillers ($n = 44$). For each target utterance, there was exactly one switch in the contextualising utterance prior to the target item. Moreover, in bilingual mode, half of all contextualising utterances began in English ($n = 88$) and half in Spanish ($n = 88$). In the bilingual mode, all fillers contained at least one language switch.

In order to prevent a clearly predictable pattern, the location of the target token (i.e. target token is nth lexical item in the contextualising utterance) was varied (Range = 4–12, $M = 6.09$, SD = 1.60). A repeated measures ANOVA demonstrated that there was no significant difference in the location of the target token across conditions ($F(7, 248) = 1.14$, MSE = 2.48, $p = .341$, $\eta_p^2 = .031$). Moreover, in the bilingual mode, the target token varied with respect to the preceding switch within the contextualising utterance, with the target token ranging from the second to sixth word post-switch ($M = 3.3$, SD = 1.1). Again, there was no difference in the position of the target token across the bilingual mode conditions ($F(3, 124) = 1.63$, MSE = 1.28, $p = .186$, $\eta_p^2 = .037$).

In total, each block contained 176 contextualising utterances. Table 3 illustrates the distribution of target tokens by block.

Semantic predictability norming study

Given that identification latency is subject to modulation by semantic predictability, such that semantically predictable items lead to shorter reaction times (e.g. Duffy, Henderson, & Morris, 1989; Schwartz & Kroll, 2006), a norming study was conducted to ensure that stimuli were similarly semantically predictable across contexts. A total of 11 Spanish–English bilinguals, different from those in the main study, participated in the semantic predictability norming study. Again, the Spanish–English bilinguals consisted of both English-dominant and Spanish-dominant participants. Five English-dominant participants self-rated as more proficient in English ($M = 6.0$, SD = 0.0) than Spanish ($M = 5.0$, SD = 0.7) and learned English from birth and Spanish (AoA: $M = 15.6$, SD = 0.9) later in life. Likewise, the six Spanish-dominant participants self-rated as more proficient in Spanish ($M = 6.0$, SD = 0.0) than English ($M = 5.1$, SD = 0.6), and learned Spanish from birth and English (AoA: $M = 13.8$, SD = 6.7) later in life.

Table 3. Distribution of target tokens by block.

Block	English targets		Spanish targets	
	Stay	Switch	Stay	Switch
Monolingual English block	33	–	–	33
Monolingual Spanish block	–	33	33	–
Bilingual block	33	33	33	33

A multiple-choice questionnaire was created from the original stimuli (Example 2). For each stimulus, the prompt consisted of the portion of the contextualising utterance occurring preceding the target token, and participants were asked to choose the word "most likely" to follow. Four possible options were presented, including the target token and the names for the three visual competitors. All possible options were presented in the same language, determined by the language of the target token in the original stimulus.

(2) Semantic predictability norming test – sample question

The teacher sang a song about …

a. windows
b. pots
c. spiders
d. churches

For each stimulus, a composite ratio was calculated by dividing the number of participants who correctly choose the target token by the total number of participants. As such, a composite ratio of 1.00 would indicate that all subjects chose the target token based on the preceding portion of the contextualising utterance. Given that there were four possible options for each stimulus, a ratio of .25 equates to random or chance probability. Results demonstrate a low overall level of semantic predictability ($M = 0.33$, SD = 0.26). Beyond the low level of semantic predictability, it was important to ensure similar semantic predictability between each of the eight conditions (two token types × two target languages × two language modes). To that end, a repeated measures ANOVA by target token was conducted, demonstrating no effect of condition on the semantic predictability ratio ($F(7, 224) = 1.36$, MSE = 0.95, $p = .225$, $\eta_p^2 = .041$). In short, target tokens were semantically unpredictable, and the predictability of tokens was similar across each of the eight conditions.

Audio stimuli

Each of the above described contextualising utterances and target tokens were presented to subjects auditorily. To create the auditory stimuli, the contextualising utterances and target tokens were recorded and manipulated.

Initial auditory stimuli were recorded by one female English–Spanish bilingual speaker. This speaker is considered to be an early bilingual, having learned both languages before the age of 5. Moreover, she reported daily use of both English and Spanish in the home, regular contact with both English- and Spanish-dominant communities, and frequent use of code switching. With respect to self-rated proficiency measures, on a 9-point Likert scale (1 = do not speak/understand at all; 9 = native-like), the speaker reported high levels of proficiency in both English and Spanish for both speaking (English = 9; Spanish = 7.5) and listening (English = 9; Spanish = 8).

Target utterances were presented visually and recording took place in a sound attenuated booth with a Shure Beta-54 head-mounted microphone at a 44.1 kHz sampling rate. The speaker was naïve to the purpose of the recordings, and the target tokens were not highlighted in any manner (e.g. font, colour, etc.).

Given that code switching may impact the phonetic production *preceding* the point of switch (Bullock et al., 2006), a series of manipulations were conducted to ensure that the preceding contextualising utterance did not provide any cues as to the nature of the target token (e.g. stay or switch) in the final auditory stimuli. To create each target utterance (Example 3a), an initial unique set of utterances was created in which the lexical item in the target position (dummy token) was always a non-switched token (Example 3b). To control for co-articulation, the word initial phonemes in the dummy token were matched to the word initial phonemes of the target token. The dummy token was then extracted and replaced with the target token spliced from a separate monolingual utterance (Example 3c). The same procedure was used for switched and non-switched target tokens, and the same spliced target token was used in all four contexts for each language (e.g. monolingual switched, monolingual non-switched, bilingual switched, bilingual non-switched).

(3) a. Target stimuli:
He is looking at <u>lápices</u> at the store, but they are expensive.
"He is looking at pencils at the store, but they are expensive."

b. Utterance with dummy token:
He is looking at <u>laptops</u> at the store, but they are expensive.

c. Nonswitched utterance with target token:
Me dijo que tenía que tener <u>lápices</u> para hacer la tarea de matemáticas.
"He told me that he needed to have pencils to do the math homework."

To assist in creating natural transitions at the point of splice, the word preceding the target token always ended in a voiceless stop, voiceless fricative, or flap (i.e. /t/, /ɾ/, /s/). To control for the intensity of the target token, and ensure that the target token intensity was within the local intensity range, the average intensity for the target tokens was scaled to the average intensity of the most immediately preceding stressed vowel using Praat v.5.1.04 (Boersma & Weenink, 2010). Similarly, to ensure a natural pitch contour, the pitch contour of the target token was manipulated *only* when the maximum or minimum f_0 of the target token was outside the f_0 range of the contextualising utterance. In these cases, to ensure natural-sounding stimuli, the entire pitch contour of the target token was shifted so that the maximum (or minimum) f_0 of the target token was equal to the maximum (or minimum) f_0 of the contextualising utterance. A total of 32 target token pitch contours (out of a total of 264) were manipulated (*mean shift* = 9.55 Hz, SD = 13.72 Hz). Finally, the entire utterance, containing the spliced target token, was scaled to a mean intensity of 50 dB.

Visual stimuli

A total of 66 black-and-white line drawings (33 target, 33 filler) were used in the visual stimuli (Snodgrass & Vanderwart, 1980). Accompanying each auditory stimulus (contextualising utterance containing the target token), the visual stimuli were presented as part of a four-picture visual world paradigm (see Figure 1). The image corresponding to the auditory target token was presented alongside three visual competitors. All images were scaled to a maximum of 200 pixels. Images were presented such that the centre of the image was 253 pixels from the edge of the screen. Position of the target image in the visual world display was randomised.

Controlling for potential phonetic competition, the target token did not share an initial phoneme with the names associated with any of the visual competitors in either English or Spanish. Moreover, none of the names associated with the visual competitors shared an initial phoneme with each other within a given language (English or Spanish).

In total, each image (target and filler) was presented a total of 32 times: eight times corresponding to the auditorily presented target token and 24 times as a visual competitor.

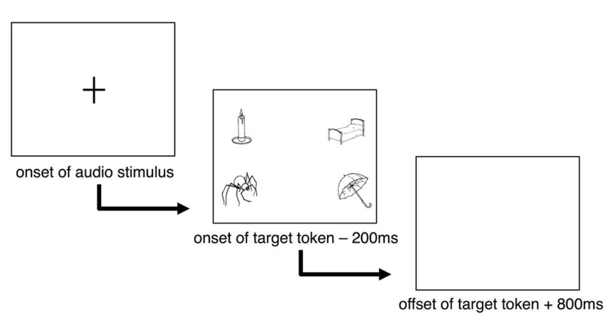

Figure 1. Time course of stimulus presentation.

Procedure

Participants' eye movements were recorded at a rate of 1000 Hz using the SR Research EyeLink 1000-table-mounted eye-tracker (SR Research). Participants' heads were stabilised using a table-mounted chinrest, and only the right eye was tracked. One centimetre on the visual deiplay corresponded to approximately 1.36° of visual arc. Nine-point calibration and validation processes were performed before the start of the experiment and between each block of stimuli. A single fixation point was presented in a random location on the screen every 10 trials for drift correction.

Each trial began with the visual presentation of a fixation cross and the start of the contextualising utterance. At 200 ms prior to the onset of the auditory presentation of the target word (Huettig & McQueen, 2007), the visual stimulus was presented, consisting of the image of the target token and all three competitors. The visual stimulus remained on the screen for 800 ms following the offset of the auditorily presented target token. The screen was blank (white) for the remainder of the auditory presentation of the contextualising utterance. Following the offset of the contextualising utterance, there was an interstimulus interval of 500 ms prior to the onset of the following audio stimulus. Each target word ($n = 33$) was auditorily presented eight times, once per condition (two token types × two target languages × two language modes). The time course of stimulus presentation is represented in Figure 1.

Each block began with a series of instructional slides. To further control for language mode, the language of the slides corresponded to the dominant language of each block. As such, the monolingual English block began with instructions in English. The bilingual block began with instructions that were presented half in English (53 words) and half in Spanish (54 words). For any interaction with the subject (e.g. during calibration), every attempt was made by the experimenter to speak predominantly the dominant language of the ensuing block. Each block lasted approximately 10 minutes, and participants were given a self-paced break between each block.

The order of stimuli within each block was randomised, and each participant received a different randomised order. The ordering of the blocks was counterbalanced across all participants.

Data analysis

Data were recorded using the EyeLink software (SR Research) and fixations were recorded with respect to the onset of the auditory presentation of the target token. Spatially, fixations were coded with respect to pre-determined areas of interest corresponding to the predetermined rectangles within with each of the visual stimuli were presented. Only fixations within the predefined areas were included in the analysis. Thus, for each stimulus, the *reaction time* represents the temporal delay between the onset of auditory presentation of the target token and onset of the fixation on the correct visual stimulus.

A total of 6600 tokens were included in the initial analysis (25 subjects × 33 target tokens × 8 conditions = 6600 tokens). Given the inherent delay between auditory presentation and the earliest possible eye movement resulting from comprehension (Huettig & McQueen, 2007), all tokens with reaction times less than 200 ms were eliminated (1.5%). In addition, for each participant, all reaction times greater than 2 standard deviations from the mean were eliminated (4.4%). In total, 5.9% of the data were eliminated, resulting in a total of 6210 tokens included in the statistical analysis.

Three main factors were considered in the initial analysis of the dependent variable *reaction time*: token type (stay vs. switch), target language (L1 vs. L2), language mode (monolingual mode vs. bilingual mode). Target language was coded such that L1 corresponded to a participant's dominant language. For example, for English-dominant participants, L1 corresponded to English and L2 Spanish. To normalise the distribution of the reaction time measurements for statistical analysis, data was subjected to a log-transformation (e.g. Judd & Sadler, 2003). In addition, to parallel previous research conducted in production (e.g. Meuter & Allport, 1999), reference is made to *switch costs*, defined as the difference between the reaction time for a given token in a switched vs. non-switched condition. Statistical analysis was conducted using R statistical software v3.1.2 (R Core Team, 2013) and the LME4 package (Bates, Maechler, Bolker, & Walker, 2015). The significance criterion was set at $|t| = 2.00$.

Results

Analysis of reaction times

Initial statistical analysis was conducted using a linear mixed model with fixed factors of token type, target language, and language mode. Participant and item (i.e. token) were included in the model as random factors, with both random slopes and intercepts for each of the main factors and their interactions (Barr, Levy, Scheepers, & Tily, 2013). Results of the initial model demonstrate a significant effect of token type, specifically a difference between the Intercept (stay in

L1 of the monolingual mode) and switch (switch in L1 of the monolingual context: $\beta = .038$, $t = 4.16$), and target language ($\beta = .050$, $t = 3.37$). In addition, the two-way interactions between token type and language mode ($\beta = -.042$, $t = -2.76$) and token type and target language ($\beta = -.031$, $t = -2.04$) were significant. Lastly, and most important for the current study, the three-way interaction between all main factors was significant (token type × target language × language mode: $\beta = .036$, $t = 2.09$). The results for all fixed effects are presented in Table 4. Results for random effects are found in Appendix 3.

To assess the relevance of each of the main fixed effects for the model, three additional models were conducted, each eliminating one of the fixed effects. The remainder of the model parameters remained the same. The first model, including all three factors, was then compared to each of the subsequent models. The results indicate that the inclusion of each of the factors improved the overall fit of the main model. Specifically, the main model (log likelihood = 3018.5) represented a significantly better fit than the model excluding the factor token type (log likelihood = 3011.0, $\chi^2(4) = 15.17$, $p = .004$), and the model excluding the factor target language (log likelihood = 3010.3, $\chi^2(4) = 16.55$, $p = .002$), as well as a marginally better fit than the model excluding the factor language mode (log likelihood = 3014.0, $\chi^2(4) = 9.13$, $p = .057$). As such, all three factors warrant inclusion in the current model. Figure 2 and Table 5 illustrate the mean reaction times across the various conditions.

To better understand the interactions between the three fixed effects above, two separate models were conducted: one for reaction times in the monolingual mode and one for reaction times in the bilingual mode. Again, paralleling the main model, these subsequent models considered both token type and target language as fixed effects, and subject and item as random effects, with random slopes and intercepts for each of the main effects and their interactions.

Table 4. Fixed effects of LME model.

	Estimate	Std. error	t-Value	Left CI	Right CI
Intercept	2.722	0.014	192.5	2.694	2.750
Switch	0.038	0.009	4.16	0.020	0.056
L2	0.050	0.015	3.37	0.020	0.080
Bilingual mode	0.005	0.009	0.51	−0.013	0.023
Switch: L2	−0.031	0.015	−2.04	−0.061	−0.001
Switch: bilingual mode	−0.042	0.015	−2.76	−0.072	−0.012
L2: bilingual mode	−0.010	0.014	−0.67	−0.038	0.018
Switch: L2: bilingual mode	0.036	0.018	2.09	0.002	0.072

Note: Fixed effects are token type (switch, stay), target language (L1, L2), and language mode (monolingual mode, bilingual mode).

Results for the model conducted on reaction times in the monolingual mode (Table 6) reveal a significant impact of token type, with a significant difference between the Intercept (stay in L1) and the switch condition (switch in L1: $\beta = .038$, $t = 4.39$), and a significant impact of target language (stay in L2: $\beta = .050$, $t = 3.44$). For random effects, see Appendix 4. An analysis of the mean reaction times, presented in Figure 2(a), illustrates that in the monolingual mode, reaction times were slower in the switch condition than in the stay condition and slower in the L2 than the L1. Of particular note for the current study was the significant interaction between the two factors ($\beta = -.031$, $t = -2.17$). As is observable in Figure 2(a), the magnitude of the difference between the stay and switch conditions is dependent on the target language. Specifically, there was a greater difference in reaction times between stay ($M = 560.3$, SD = 209.1) and switch ($M = 609.8$, SD = 215.0) tokens in the L1 relative to the L2 (stay: $M = 631.5$, SD = 236.6; switch: $M = 642.4$, SD = 239.8). This finding is reminiscent of the previous asymmetrical switching costs observed in production paradigms (e.g. Meuter & Allport, 1999).

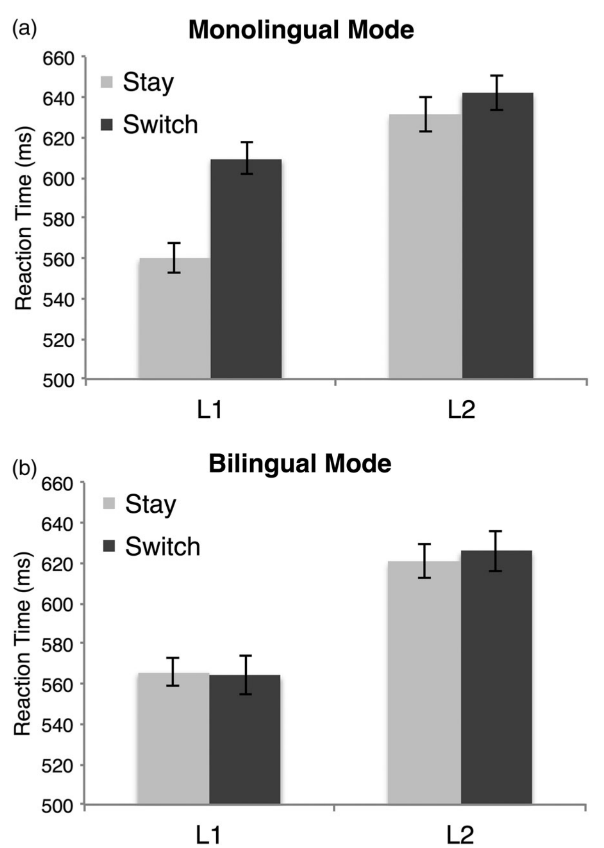

Figure 2. Mean reaction times in monolingual mode (a) and bilingual mode (b) by token type (stay vs. switch) and target language (L1 vs. L2).
Note: Error bars represent ±1 SE.

Table 5. Mean reaction times by condition.

	Monolingual mode		Bilingual mode	
	Stay *M* (SD)	Switch *M* (SD)	Stay *M* (SD)	Switch *M* (SD)
L1	560.3 (209.1)	609.7 (215.0)	566.0 (206.1)	564.4 (219.9)
L2	631.5 (236.6)	642.4 (239.8)	621.0 (228.2)	626.1 (237.2)

Table 6. Fixed effects of LME model for monolingual mode.

	Estimate	Std. error	*t*-Value	Left CI	Right CI
Intercept	2.722	0.014	194.8	2.694	2.750
Switch	0.038	0.009	4.39	0.020	0.056
L2	0.050	0.015	3.44	0.020	0.080
Switch: L2	−0.031	0.015	−2.17	−0.061	−0.001

Note: Fixed effects are token type (stay, switch) and target language (L1, L2).

Similar analysis for reaction times in the bilingual mode condition provides a differing result (Table 7). For random effects, see Appendix 5. Specifically, while there was a significant impact of target language, demonstrated by the difference between the Intercept (stay in L1) and L2 (stay in L2) ($\beta = .040$, $t = 3.89$), there was no significant impact of token type ($\beta = -.004$, $t = -0.37$), nor any interaction between the two main factors ($\beta = .006$, $t = -0.022$). That is, the difference between stay and switch tokens was similar in the L1 (stay: $M = 566.0$, SD = 206.1; switch: 564.4, SD = 219.9) and L2 (stay: $M = 621.0$, SD = 228.2; switch: $M = 626.1$, SD = 237.2). As can be observed in Figure 2(b), this lack of interaction demonstrates that the difference between stay and switch reaction times is similar, regardless of the target language.[4]

Analysis of switch costs

As a means to compare further the performance in the two language modes, and to parallel previous research, switch costs were analysed in the different target languages and language modes. Again, switch costs are defined as the difference in reaction time between a stay token and a switch token. For the current study, switch costs were calculated for each token by subtracting the mean reaction time for stay tokens in a given target language and language mode from each individual switch token in the same condition. Standard deviations were adjusted accordingly. With respect to the monolingual mode, there was a greater mean switch cost in the L1 ($M = 49.4$ ms, SD = 299.9) than the L2 ($M = 11.0$, SD = 336.9). Statistical analysis comparing the switch costs in the L1 and L2 in monolingual mode, using a two-sample *t*-test with unequal variance, confirmed the significance of the asymmetry, $t(1,\ 492) = 2.35$, $p = .019$, $d = .12$. Similar comparison for reaction times in the bilingual mode reveals similar switch costs in the L1 ($M = -1.6$ ms, SD = 301.4) and L2 ($M = 5.1$, SD = 329.1), and statistical analysis revealed no significant differences between the switch costs in the L1 and L2 in bilingual mode, $t(1,\ 556) = -0.42$, $p = .675$, $d = -.02$. Paralleling analysis by Costa et al. (2006), an examination of the magnitude of difference in switch costs (i.e. L1 switch costs – L2 switch costs) in the monolingual and bilingual mode reveals a larger magnitude of difference in the monolingual mode (38.4 ms) relative to the bilingual mode (−6.7 ms). Figure 3 illustrates the difference between switch costs in L1 and L2 in the two language modes.

Table 7. Fixed effects of LME model for bilingual mode.

	Estimate	Std. error	*t*-Value	Left CI	Right CI
Intercept	2.722	0.014	199.6	2.694	2.750
Switch	−0.004	0.011	−0.37	−0.026	0.018
L2	0.040	0.010	3.89	0.020	0.060
Switch: L2	0.006	0.014	0.43	−0.022	0.034

Note: Fixed effects are token type (stay, switch) and target language (L1, L2).

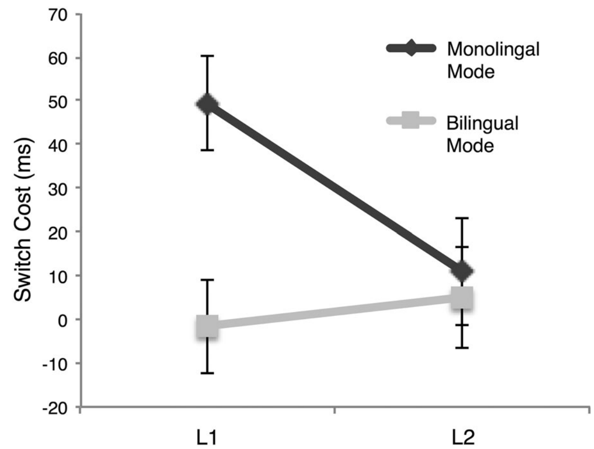

Figure 3. Switch costs by target language and language mode.
Note: Error bars represent ±1 SE.

While statistical analysis demonstrated a significant difference between switch costs in the L1 and L2 in monolingual mode and no difference in the L1 and L2 switch costs in bilingual mode, analysis of Figure 3 reveals another interpretation. Specifically, while there are clearly (asymmetrical) switch costs in the monolingual mode, there are ostensibly no switch costs present in the bilingual mode, with both L1 and L2 evidencing “costs” near zero. A Tukey post-hoc analysis of the initial mixed model for reaction times in the bilingual mode revealed no significant difference between switch and stay tokens in either the L1 ($p = .981$) or L2 ($p = .997$), confirming the lack of switch costs in the bilingual mode.

Discussion

The principle aim of the current study was to examine the potential for, and nature of, language switching costs during auditory comprehension. Paralleling the original research questions, three major findings can be drawn from the results. First, assessing the difference in comprehension latencies between stay and switch tokens, results demonstrated that switch costs are possible during auditory comprehension, although an analysis of the mean switch costs suggest that were only found in monolingual mode. Second, considering the role of individual factors, the results showed that language dominance impacted switch costs, with asymmetrical switch costs being found in monolingual mode. Specifically, in the monolingual mode, the difference between switched and non-switched tokens was greater in the L1 than the L2. Finally, the results demonstrated a modulating effect of language mode, such that in monolingual mode switch costs differed in the L1 and L2, while in the bilingual mode switch costs were uniformly absent in the L1 and L2. In the following subsections, these results will be discussed with reference to previous paradigms in bilingual production and comprehension. Moreover, preliminary implications for theories of cognitive mechanisms used for bilingual language selection are considered.

Switch costs and language dominance

With respect to the first two research questions, the results presented for the monolingual mode serve to extend previous findings of asymmetrical switch costs from production-oriented paradigms to auditory comprehension. While previous research in bilingual comprehension, most notably reading paradigms (e.g. Dussias, 1997, 2001, 2003, among others), has alluded to switch costs in bilingual speech comprehension, the current study demonstrates language switching costs in an auditory comprehension paradigm. In the monolingual mode, the current study showed a clear difference between language switching costs in the L1 and L2.[5] While comprehension of language switches in the monolingual context always incurred a reaction time cost, this cost was significantly greater in the L1 than the L2. These findings of asymmetrical switch costs directly parallel previous findings from a number of production-oriented paradigms focusing on L1-dominant bilinguals, including cued picture naming paradigms (Meuter & Allport, 1999, among many). Given the clear parallels with previous results from production-oriented paradigms, which have provided key support for an inhibitory interpretation of language switching and bilingual lexical access (Green, 1998), the current results can also be interpreted within an inhibitory control framework.

The findings of asymmetrical switch costs in production, coupled with findings from other paradigms including ERP (Guo et al., 2011; Jackson et al., 2001) and neuroimaging (Abutalebi et al., 2007; Hernandez, 2009; Hernandez et al., 2001; Price et al., 1999; Wang et al., 2007), have been taken as support for an inhibitory framework for lexical access in bilinguals. Specifically, drawing on work by Green (1998), lexical access in bilinguals is aided by an inhibitory mechanism. Given the greater strength of the dominant language network, greater levels of inhibition must be applied to the L1 network relative to the L2 network. As such, the asymmetrical switch costs seen in the previous production-oriented research are explained by the delay incurred in overcoming the differential levels of inhibition. Worth noting, although the inhibitory framework was originally conceptualised as a production-oriented model (Green, 1998), it is applicable to the current paradigm considering the focus on language switching, traditionally approached via production-oriented research, and the similarities between the current comprehension results and previous results from bilingual production tasks.

This same framework can be applied to the asymmetrical switch costs in the current, comprehension study. In monolingual mode, comprehension during the preceding contextualising utterances (Language A) drives a degree of inhibition to be applied to the opposite language (Language B). As such, comprehending a language switch into the inhibited Language B incurs a reaction time costs associated with overcoming the inhibition. Additionally, given the relative strength of the L1 and L2, greater inhibition is applied to the L1 relative to the L2 to facilitate comprehension in the opposite language. As such, comprehending a switch into the L1 incurs a greater switch cost than comprehending a switch into the L2.

This interpretation also finds tacit support from previous research on bilingual comprehension, albeit of non-switched stimuli. For example, Canseco-Gonzalez et al. (2010) demonstrated a difference in the degree of cross-linguistic activation for Spanish–English bilinguals of different language backgrounds during processing of monolingual English stimuli. Specifically, Spanish-dominant subjects, having learned Spanish as a native language and demonstrating a preference for Spanish, showed greater cross-linguistic activation of Spanish competitors than English-dominant subjects. That is, when measuring the degree of cross-linguistic activation, there is evidence of greater parallel activation of the L1 than the L2. Similarly, Blumenfeld and Marian (2007) revealed an impact of proficiency on cross-linguistic activation in German–English bilinguals, with cross-linguistic activation of German words during English comprehension limited for bilinguals with lower levels of German proficiency (see also Marian & Spivey, 2003). As a whole, these results are indicative of a greater strength of the L1 network. Interpreting these results within an inhibitory framework, to compensate for the greater cross-linguistic activation of the L1, a greater level of inhibition must be applied to the L1 network relative to the L2 to facilitate comprehension, and as such, switching into the L1 would entail overcoming this greater inhibition.[6]

Although comparison of the various models of bilingual lexical access is beyond the scope of the current paper, it is worth briefly considering a more comprehension-oriented model, such as the Bilingual Interactive Activation Plus (BIA+).[7] While the BIA+ (Dijkstra & van Heuven, 2002) shares much in common with the ICM (Green, 1998), one key difference is the absence of top-down inhibition on lexical activation in the BIA+ approach. Discussing the BIA+ model, van Heuven and Dijkstra (2010) suggest that, "suppression of non-target language word candidates does not seem as likely in language comprehension" (p. 117). As such, the BIA+ model would predict that the language of a given paradigm would not impact the time-course of word identification. In contrast, the ICM, with a globally reactive top-down application of inhibition on a given language, would predict that the predominant language in a paradigm could alter word identification latency. With respect to the current results, the clear difference in the comprehension latencies between switch and stay trials, particularly in the monolingual mode, imply some top-down mechanism to minimise competition from the non-target language of a given paradigm. While the ICM explicitly defines such a mechanism (i.e. inhibition), it is not clear how the BIA+ would account for such results.

While Macnamara and Kushnir (1971) proposed two separate language switches, one for production and one for perception, the current results from the monolingual context suggest that a similar cognitive mechanism may potentially account for both production and comprehension. This proposal is also in-line with the findings that the cognitive mechanisms responsible for language switching and selection are not language specific (or production specific), but rather an application of a general cognitive mechanism (e.g. Bialystok et al., 2009). While a similar mechanism would not necessarily preclude differential application of inhibition to production and comprehension systems (for the dissociation of language control mechanisms in production and perception, see Blanco-Elorrieta & Pylkkänen, 2016), it is possible that a similar underlying process is employed. Further research will serve to better identify the mechanism responsible for language switching costs during comprehension and the potential interconnection between language switching mechanisms in production and comprehension.

Switch costs and language mode

With respect to the third research question, the current study showed an impact of language mode on switch costs during comprehension. While switch costs were asymmetrical in the monolingual mode, with subjects being slower to comprehend switches into the L1 than the L2, switch costs were uniformly absent from both the L1 and L2 in bilingual mode. Again, these results parallel previous findings in production from the cued language switching paradigm. Specifically, Olson (2016) showed asymmetrical switch costs in monolingual mode, with subjects incurring a greater cost when switching into the L1 relative to the L2, while symmetrical (albeit not absent) switch costs were found in a bilingual mode. More broadly, these findings can be couched within the larger trend for a degree of flexibility in switch costs driven by contextual factors, as also seen in non-cued switching paradigms (Gollan & Ferreira, 2009), manipulations of inter-stimulus intervals (Verhoef et al., 2009), and limited switch costs for cognates (Declerck et al., 2012). In addition, while the current study was not designed to address the impacts of recency, tentative post-hoc analysis demonstrated that while recency may play a role in determining the magnitude of switch costs, language mode impacted the relationship between switch costs in the L1 and L2 (i.e. asymmetrical vs. symmetrical switch costs).

With respect to an inhibitory framework, Green (2011) proposed a potential impact of a bilingual speaker's "ecology", with the norms of the speech community influencing lexical access (see also Green & Abutalebi, 2013). Olson (2016) proposed extending the notion of flexibility to include language mode, arguing for a gradient interpretation of inhibition subject to both individual (e.g. dominance) and contextual (e.g. language mode, speaker ecology, etc.) factors. In this interpretation, the degree of inhibition applied to a given set is driven by global factors, as opposed to solely local factors such as the immediately preceding lexical item.[8] Support for globally driven inhibition mechanisms can also be found in studies that have shown global language mixing costs, in which longer naming latencies for non-switched stimuli are found in mixed language tasks relative to unilingual language tasks (Christoffels et al., 2007; Declerck, Philipp, & Koch, 2013; Gollan & Ferreira, 2009; Wang, Kuhl, Chen, & Dong, 2009). This interpretation may account for the current results as well. While operation in a monolingual mode entails applying maximal inhibition to the non-target language leaving the target language with minimal competition, operation in a bilingual mode may drive inhibition such that both languages become (relatively) equally accessible. In the current paradigm, participants in a monolingual English mode may apply maximal inhibition to their Spanish network, while operation in a bilingual mode may drive roughly equal levels of accessibility in the two languages.

A similar analysis can be applied to previous findings from a perceptual approach, albeit with non-switched stimuli. For example, Dijkstra and colleagues have shown a reaction time delay for go/no-go lexical decision tasks involving cross-linguistic homophones when stimuli were drawn from two languages. In contrast, when stimuli consisted of a single language, there was no difference in performance for cross-linguistic homophones and non-homophonic targets (Dijkstra et al., 1998, 2000). This additional delay, seen only in bilingual mode, may derive from the relatively equal accessibility of and increased competition between the two languages. Similarly, from an eye-tracking paradigm, Marian and Spivey (2003) demonstrated a greater degree of cross-linguistic activation of the non-target language during operation in a bilingual mode relative to operation in a monolingual mode. Coupled with the results from the current study, these results suggest that language mode may play a role during comprehension, specifically with the non-target language more effectively inhibited during monolingual mode relative to bilingual mode.

One notable point of departure from previous production-oriented research is the lack of global language mixing costs (e.g. Gollan & Ferreira, 2009) in the current results: when non-switch responses in the L1 are slower in mixed blocks than pure blocks. It might be expected that in the bilingual mode, with relatively equal inhibition applied to both languages, and as such, increased numbers of lexical competitors, non-switched responses would evidence longer reaction times. However, in the current study, there is little difference (6 ms) between L1 stay tokens in the monolingual and bilingual conditions, a clear contrast with previous findings (Olson, 2016). To better understand this effect, future work may seek to address local and global mixing costs during comprehension and specifically their relation to production-oriented findings.

Conclusion

While bilinguals can switch "seamlessly" between their two languages in naturalistic speech, research in production has consistently shown that such switches incur a small reaction time delay (i.e. switch cost) (e.g. Meuter & Allport, 1999), although such costs are subject to both individual (e.g. Costa & Santesteban, 2004) and contextual factors (e.g. Olson, 2016). Switch costs have been crucial for developing theories regarding the cognitive mechanisms for language switching. The current study, employing a visual world eye-tracking paradigm, demonstrated similar switch costs during language comprehension. Considering the role of an individual factor (i.e. language dominance), these costs were shown to be asymmetrical in monolingual mode, with greater costs evidenced in the L1 than the L2. Moreover, switch costs were shown to differ based on a contextual factor (i.e. language mode), such that costs were asymmetrical in monolingual mode and uniformly absent in bilingual mode. These results may find one tentative explanation within a gradient interpretation of an inhibitory framework (Green, 1998). In such an approach, the non-target language must be inhibited, but the degree of inhibition may be impacted by the larger context. Namely, comprehension in monolingual mode involves maximal inhibition of the non-target language, although levels of inhibition may relate to overall strength of each language, with greater inhibition applied in the L1 relative to the L2. Comprehension in a bilingual mode implies differential inhibition such that each language remains relatively equally accessible.

The current study represents an initial approach to language switching costs during auditory comprehension, and further research should address both the nature and scope of such costs. For example, future research may address the differential and/or interrelated contributions of language mode and recency, as well as the role of proficiency. Furthermore, while the current results may be couched within an inhibitory framework, future work may seek to account for such results in comprehension through different proposals.

Notes

1. Language mode has been shown to impact the type and frequency of language switches (e.g. Treffers-Daller, 1998) and phonetic production (e.g. Khattab, 2003, 2009; Olson, 2013, 2015; Simonet, 2014).
2. Worth noting, the potential role of inhibition in language selection is the subject of some debate (for review, see Bobb & Wodniecka, 2013). Others have proposed a more direct access mechanism for balanced bilingual populations (e.g. Costa, 2005; Costa et al., 2006; Finkbeiner, Almeida, Janssen, & Caramazza, 2006; Finkbeiner, Gollan, & Caramazza, 2006; Paradis, 1980, 2004) or a system in which asymmetrical switch costs are motivated by the relative strength of activation perseverance for the L1 and L2 (Verhoef et al., 2009). While an inhibitory framework is adopted for the current discussion, in part due to the focus on L1-dominant bilinguals, it is possible that the results of the current study would find explanation within alternative approaches.
3. It is readily acknowledged that the blocks termed "monolingual mode" are likely not truly monolingual.

Many researchers have noted the limitations on creating a monolingual mode in an experimental setting (e.g. Marian & Spivey, 2003). However, paralleling previous research (Olson, 2016; Simonet, 2014), it is assumed that the monolingual modes are *relatively* more monolingual than the bilingual mode.

4. As noted by a reviewer, in the current design there is a conflation between recency and language mode, with targets in the bilingual mode more recently preceded by a language switch relative to those in the monolingual mode (for evidence for the role of recency, see Blanco-Elorrieta & Pylkkänen, 2016). While the current study was not expressly designed to assess the relative contributions of language mode and recency, the variability in target token placement allowed for a post-hoc analysis. To examine the potential role of recency, in the bilingual mode, tokens were coded with respect to the number of intervening lexical items between the preceding language switch and target token, and grouped as either high recency (2–3 words post-switch) or low recency (4–6 words post-switch). A LME model was conducted on reaction times (log transformed), with response type, target language, and recency as main effects and subject as a random effect with random slopes and intercepts for each of the main effects. Results demonstrated no significant impact of recency on reaction times ($\beta = .009$, $t = -0.80$), and no significant two-way or three-way interactions involving recency ($|t| < 2.00$). In monolingual mode, distance from the utterance onset was employed as a proxy for distance from the previous switch (high recency: 3–5 word; low recency: 6–11 word). Similar analysis revealed that while there was a significant effect of recency ($\beta = .037$, $t = 3.32$), there were no two- or three-way interactions between recency and any of the other main effects ($|t| < 2.00$). These results suggest that while recency may play a role in switch cost magnitude, language mode is the key factor in determining the relationship between switch costs in the L1 and L2 (i.e. symmetry vs. asymmetry).
5. Again, here L1 and L2 in the current study are representative of the dominant and non-dominant languages, respectively. Drawing on previous findings (e.g. Schwieter & Sunderman, 2008), proficiency may be a more significant factor than order or age of acquisition.
6. It should be noted that applying inhibition to a given token does not completely eliminate cross-linguistic activation (e.g. Marian & Spivey, 2003).
7. While the BIA+ Model (Dijkstra & van Heuven, 2002), like the original BIA model (Dijkstra & van Heuven, 1998), is rooted in orthographic word comprehension, it represents a valuable point of comparison with the fundamentally production-driven ICM (Green, 1998).
8. It would be plausible to posit that recency may be considered a local effect, while language mode a global effect. Further research should seek to confirm the potential relationship between recency and language mode.

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