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An Investigation Of The Loci Of Bilingual Switch Costs During Reading Comprehension

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AN INVESTIGATION OF THE LOCI OF BILINGUAL SWITCH COSTS DURING

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Abstract

In the present study, we examined whether the comprehension of language switches can be accounted for exclusively by activation dynamics within the lexicon, or whether there is evidence that cognitive general control processes outside of the lexicon are also engaged. In Experiment 1 we compared the fixation durations made on words embedded in either language pure or language switched sentences. The critical words were either cognates or non-cognate controls and served as the switch point in the language switched versions of the sentences. An overall switch cost was observed, which did not interact with cognate status or direction of the switch. In Experiment 2, we found that the language switch cost was attenuated when a non-linguistic color cue was present. These findings are most consistent with a general task–switching mechanism that operates outside of the lexicon.

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Chapter 1: Bilingual Language Switch Costs

Although bilinguals can switch between languages with apparent ease, whether it be during speaking, comprehending speech, or reading a text (e.g., Wang, 2015) there is a cost in processing time, referred to as a switch cost. Numerous studies have examined switch costs as a way to elucidate the cognitive mechanisms involved in selection of a language (Bultena, Dijkstra, & van Hell, 2015a, 2015b; Caramazza & Brones, 1980; Grainger & Beauvillain, 1987; Green, 1998; Jared & Kroll, 1999; Thomas & Allport, 2000; Von Studnitz & Green, 1997; Wang, 2015). Theoretical accounts differ in whether they assume that language switching is based on general executive control mechanisms outside of the lexicon (Abutalebi & Green, 2007; Green, 1998) or whether they are based on fluctuating levels of activation within the lexicon (Dijkstra & Van Heuven, 2002).

Most of the research on language switching has focused on language production, in which the intention to switch is internal to the speaker (Grosjean, 1998; Meuter & Allport, 1999; Thomas & Allport, 2000). Less research has addressed comprehension of language switches, in which the switch is exogenous and stimulus-driven (Grainger, Midgley, & Holcomb, 2010; Bultena, Dijkstra, & van Hell, 2015; Wang, 2015). As a consequence, it is still not clear whether the same mechanisms operate in the comprehension of switches as those in production. According to the bilingual interactive activation plus (BIA+) model (Dijkstra & Van Heuven, 2002), the most widely cited and tested model of bilingual lexical access, comprehension of switches is based solely on processes within the lexicon. This contrasts with the assumptions of the inhibitory control model (ICM) (Abutalebi & Green, 2007; Green, 1998), one of the most widely tested models of language control. According to the ICM, language switching in general, whether it be in comprehension or production, can be carried out by processes both within and outside of the lexicon. The goal of the present study was to test the alternative assumptions of these two models in a sentence comprehension study. What follows is a more detailed description of the two models and summaries of supporting studies.

1.1 Inhibitory Control Model (ICM)

According to the ICM (Abutalebi & Green, 2007; Green, 1998), language control starts with the formation of a conceptual representation of the desired message, which is formulated within the conceptualizer (see Figure 1). The intention to communicate the message in a particular language is overseen by a general supervisory system, called the Supervisory Attentional System (SAS), which transmits this attention to a system of language task schemas. Language task schemas are networks of representations that specify components of a specific task. These language schemas modulate activation levels of lexical representations within the lexicon by activating representations consistent with the schema and inhibiting those inconsistent with the schema. Language task schemas compete with each other and thus maintaining one schema involves active inhibition of a competing schema. Evidence for the operation of task schemas comes from a study by Von Studnitz and Green (1997) in which greater language switch costs were observed in a language-specific lexical decision task relative to a language general lexical decision task. In both versions of the task competitive dynamics amongst words across different languages in the lexicon incur a general cost of switching. In a language-specific lexical decision, one of the language task schemas must be inhibited, thereby incurring an additional cost when the task schema must be switched.

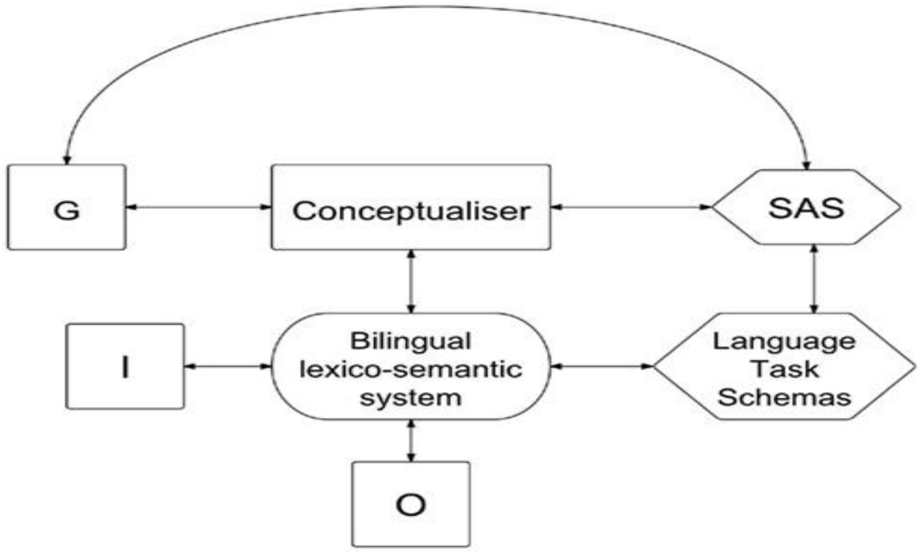

Figure 1. The Inhibitory Control Model (ICM) (Green, 1998).

In an L2, language pure lexical decision task the same authors demonstrated that bilinguals can adaptively control how they respond to incoming language membership cues. First, they found that when foil words from the non-target language (requiring a "no" response) were included in the stimulus list there was increased interlingual homograph interference. Also, they observed carry-over effects, such that responses to high-frequency L2 words were slower when these immediately followed a foil word from the non-target language. The interpretation is that the presence of words from the non-target language led participants to adapt their word-decision criteria.

1.2 Bilingual Interactive Activation Plus (BIA+) Model

Alternatively, the BIA + (Dijkstra & Van Heuven, 2002) assumes that the relative ease with which a language switch is comprehended is based solely on bottom-up activation dynamics within the lexicon (see Figure 2). This model does not allow for external sources of information (expectations, non-linguistic cues) to directly alter the relative activation of a language in the lexicon. Instead, how quickly a word is identified, whether it be language switched or language pure, is the result of its resting level of activation and its match to the stimulus input. As such a language switch cost can arise through two mechanisms. First, if the switched word is from the L1 to the weaker L2, processing the L2 switched word is slowed because it takes a longer time to retrieve relative to an L1 word. Second, previous stimulus input from language *A* can decrease the resting activation level of words in language *B*, thus switching into *B* requires a greater amount of activation.

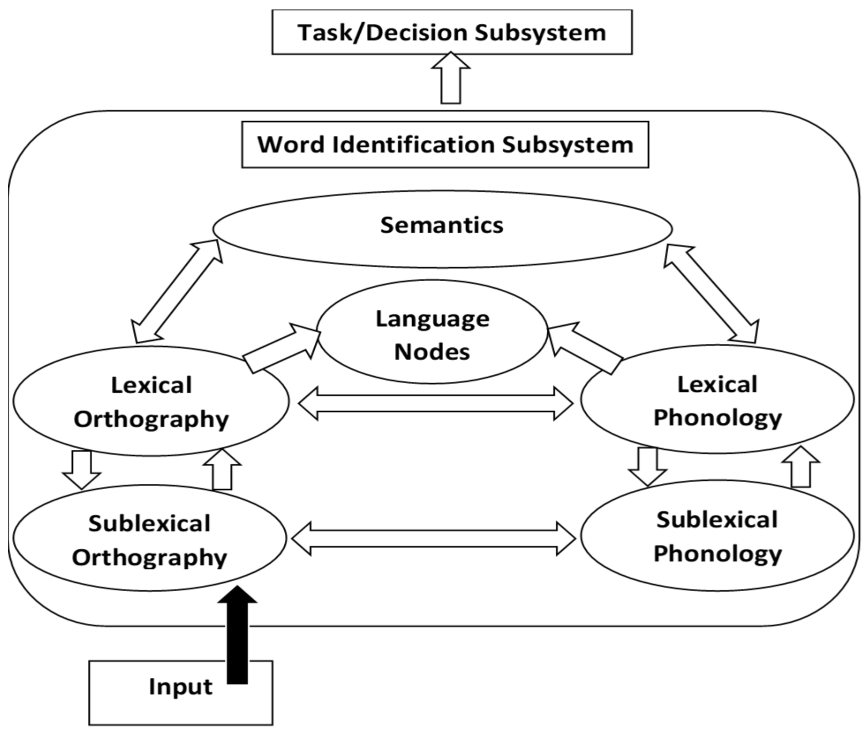

Figure 2. Bilingual Interactive Activation Plus model (BIA+) (Dijkstra & Van Heuven, 2002).

The authors of the model cite a study by Grainger and Beauvillain (1987) as support for the assumption that switch costs are driven exclusively by activation and inhibition within the lexicon. In Experiment 1 English-French bilinguals performed a language-general lexical decision task across 3 types of blocks; one in which all words were English, one in which all words were in French and one in which words were from both languages. During the experiment, participants were asked to respond "no" if the word was in the non-target language. Lexical decision times were significantly longer in the mixed block relative to either language-pure block, furthermore, the cost was greatest when the preceding trial was a word in the opposite language. This cost of mixing can be accounted for by fluctuating levels of activation of lexical representations across the two languages, seeing words across both languages maintains the activation of their associated words, increasing competition. The critical result for the BIA+ was from Experiment 2 in which they manipulated whether words had language-specific orthographic patterns. If language inhibition during comprehension is solely based on activation and inhibition within the lexicon, then the presence of language-unique cues should limit the activation of words from the other language, thereby reducing the language switch cost. Consistent with this prediction, the presence of language-specific cues eliminated a language switch cost.

A few studies have shown an asymmetrical switch cost incomprehension, with larger costs when switching from L1 to L2 (Bultena, Dijkstra, & van Hell, 2015a, 2015b; Litcofsky & Van Hell, 2017; Wang, 2015). The BIA + can account for this asymmetry by assuming that lexical retrieval takes longer for L2 words than for L1 words. Two similar tested this explanation with highly-proficient Dutch-English bilinguals (Bultena, Dijkstra, & van Hell, 2015a, 2015b). In the first of the two studies, Bultena and colleagues (2015a), the authors examined reading latencies of words that preceded a either a language switched or non-switched verb that was either a cognate or a non-cognate control. They found that there was a greater switch cost when switching into the L2. Moreover, they did not find that switch costs were modulated by the verb cognate.

In the second of the two studies participants were asked to shadow spoken sentences, and similar to the first study the language switch was either from L1to L2 or L2 to L1 before the presentation of a verb cognate manipulation (Bultena, Dijkstra, & van Hell, 2015b). They predicted that if switch costs are due solely to the time to retrieve a lexical representation, then the asymmetrical L1-L2 switch cost should be replicated and that a switch into a cognate would eliminate the asymmetry. As in the first study, they found an overall cost of switching, in which the magnitude was greater in the L1-L2 direction. which is consistent with the BIA+ assumption that switch costs in comprehension are due to the time to lexically retrieve a word in the less dominant language. As in the first study, the switching cost was not modulated by cognate status. They attributed the lack of a cognate effect to the fact that these were verbs. This interpretation is inconclusive since there was no cognate noun condition to test whether this was, in fact, the case.

1.3 Developmental Framework of the BIA+ (BIA-d)

Another alternative is provided by a developmental framework of the BIA+ known as the BIA-d has been proposed (Grainger, Midgley, & Holcomb, 2010). According to this model, words in each language are connected to a language node. Thus, greater activation of language nodes will produce greater activation of words. Therefore, language switches are facilitated by language node activation that is driven by both endogenous (top-down) and exogenous (bottom-up) control mechanisms. For example, during speech production, bilinguals elicit more of an endogenous control mechanism, which is a top-down process that is not stimulus-driven. Therefore, the endogenous (top-down) control mechanism will have an impact on long-term processing, and in turn, this mechanism will strengthen the language nodes utilizing inhibition of the irrelevant language within the lexicon. On the other hand, during text comprehension bilinguals elicit more of an exogenous control mechanism, which is a bottom-up process that is short-lived and more stimulus-driven. Therefore, the exogenous (bottom-up) control mechanism will impact language switching because it is based on fluctuating levels of activation within the lexicon. Specifically, there will a larger switch costs when switching into L2 because L1 words have a higher resting level activation, exerting more inhibition of L2 words. In other words, inhibition and activation of relevant and irrelevant words are guided by these two inhibitory control mechanisms within the lexicon. Therefore, this model provides supporting evidence for the theory that language switch costs originate within the lexicon.

1.4 Recent Findings

Wang (2015) also examined the comprehension of language switches. Specifically, they examined switching costs in English-Chinese bilinguals during a maze task. In this task, participants had to complete sentences by choosing one of two alternative words presented on the screen one pair at a time (e.g. “The… rain/were - but/fell - clock/silently”). Sentences were similar in translation and consisted of a switch or a non-switch trial. In the switch trials, the switched word was a Chinese noun, and the alternative word was also a noun. This would allow them to gain a better understanding of switch costs at the lexical level. One relevant finding was that the English-dominant bilinguals took more time choosing the alternative words in Chinese within an all English sentence. These results provide supporting evidence for the lexical retrieval account provided by the BIA+. On the other hand, they found an overall switch cost irrespective of language dominance. These results were interpreted as an inhibitory effect, which is in line with a top-down inhibition process that is assumed by the ICM.

More recently, Litcofsky and Van Hell (2017), investigated comprehension of language switches through self-paced reading (Experiment 1) and electroencephalography (EEG) (Experiment 2) with Spanish-English bilinguals. Across both measures, they observed a general processing cost for switched versus non-switched words, a cost for switched words with a slightly larger cost in the L2-L1 direction.

1.5 The Present Study

The findings of the present study will provide some clarity to unanswered questions from the literature by providing a systematic examination of four different hypothesized sources of switch costs during comprehension. Each hypothesis makes a distinct set of predictions regarding the effects of a language switch, the direction of the switch and the effect of cognate status on the processing of the switch. These are summarized in Table 1.

Table 1: Predicted effects for four hypothesized loci of switch costs during comprehension

Hypothesized locus	Predicted effect	Cognate status
lexical activation	cost in processing L2 words relative to L1 no effect of language switch	attenuate L2 processing cost
language activation	Overall cost for switched words greater cost from L1-L2	Attenuate cost
language inhibition	Overall cost for switched words greater cost from L2-L1	no effect
Task schema activation	Overall cost for switched words; greater cost from L1-L2	no effect

One hypothesized source of the switch cost during comprehension is that it is solely due to the time it takes for the strength of lexical activation to surpass the threshold for retrieval. We will call this the "*lexical activation*" hypothesis. This hypothesis predicts slower processing times for L2 words, regardless if a previously switched word or not. It also predicts faster processing times for cognates, irrespective of a previous switch or not.

A second hypothesized source of switch costs is that comprehending a language switch involves increases in the global activation of the switched language.

This "*language activation*" hypothesis is compatible with the assumptions of the BIA+ and leads to the prediction that processing times should be slower for switches from the L1 to L2 direction since the L2 has an overall lower resting level activation relative to the L1. However, this hypothesis allows for the possibility of a greater cost in comprehending an L2-L1 with increasing time spent processing in the L2, as this might cause the global resting activation level of the L1 to decay. Finally, this hypothesis leads to the prediction that any cost in comprehending a switch should be attenuated when the switched word is a cognate since these have a higher resting activation level relative to noncognates.

Alternatively, comprehending a language switch may involve global inhibition of the pre-switch language. According to this "language inhibition hypothesis," processing times should be longer for L2-L1 switched words because the L1 requires more inhibition when comprehending the L2, and the time to overcome this inhibition will be longer relative to when switching into the L2, which requires less inhibition. This hypothesis is compatible with the assumptions of the ICM, but not the BIA+, which does not allow for global inhibition of a language.

A fourth hypothesized source of switch costs is that comprehension is delayed because different language task schemas are co-activated and selecting one requires resolving competition amongst these. We will call this the "task activation" hypothesis. If language switching costs are based solely on competition amongst task schemas, then we should observe delayed processing at a language switch, irrespective of the direction of that switch. It should also not be attenuated by the cognate status of the switched word. While the IC model does include a task schema mechanism, the model assumes that this operates in conjunction with competition within the lexicon as well. Thus, the model predicts a switch cost that should be modulated by the direction of the switch and possibly cognate status. When considering the possible operation of task schemas in the comprehension of language switches it should be noted that during comprehension, the switch is stimulus-driven. Therefore, comprehension might not typically recruit task switching, executive control processes in the way that producing a switch does. Also, during comprehension there is usually not a reliable cue, that is not lexical in nature, and that can signal a language switch. The absence of cues might limit the ability of the cognitive system to recruit executive control processes.

These four hypothesized loci are not necessarily mutually exclusive as some of these mechanisms that may operate in parallel. By examining the pattern of effects that emerge in the proposed study design we can discern which source or combination of sources underlie mixing and switch costs in bilingual lexical processing. The possible operation of these four mechanisms were tested through two eye-tracking experiments with highly-proficient Spanish-English bilinguals. In Experiment 1 the four possible loci were tested by comparing reading times of target words as a function of three factors: whether they were in the L1 or the L2, a language-switched word or not; and their cognate status. In Experiment 2 the possible operation of cognitive general control processes in comprehension language switches was further assessed by implementing a nonverbal (color) cue of mid-sentence switches to assess if such cues facilitate the processing of switches.

1.6 Experiment 1 Goal

The goal of Experiment 1 was to assess the potential roles of the four, proposed mechanisms of language selection, namely: (1) lexical activation (2) language activation (3) language inhibition and (4) task schema activation. If the time it takes to comprehend a language switch is solely based on the time it takes to activate the switched word, then item-specific characteristics, in this case, cognate status and its L1 versus L2 status, should increase processing latencies, and not be modulated by language switch conditions. If comprehending a switch is influenced by the need to globally activate a language then the processing time of target words should be slowest when they constitute an L1 to L2 switch. If selecting a language for comprehension involves active inhibition of a language, then comprehending in an L2 should require a greater degree of inhibition of the competing L1. As a consequence, the processing time of L2 to L1 switched words should be longer than L1 to L2 or language pure conditions. Finally, if comprehending language switches engages a cognitive general, task switching control mechanisms, then processing times should be longer for words that are language switched, irrespective of the direction of the switch or cognate status.

1.7 Experiment 1 Method.

1.7.1 Power analysis and sample size.

A statistical power analysis was computed using G*Power, and for the present study, 36 participants were needed to detect a medium effect with .87 power (Erdfelder, Faul, & Buchner, 1996).

1.7.2 Participants.

Participants were Spanish-English bilinguals recruited from the University of Texas at El Paso (UTEP). Language proficiency was measured through the Woodcock-Munoz Language Survey (WMLS-R) (Woodcock, Muñoz-Sandoval, Ruef, & Alvarado, 2005). The WMLS-R is a standardized measure of language proficiency in English and Spanish. One score derived from this measure is the cognitive-academic language proficiency (CALP) level, which reflects language proficiency in an academic setting (Cummins, 1984). The CALP levels range from 6 to 1 (Negligible). The CALP level in English and Spanish was derived from performance on four subtests: (1) picture vocabulary, (2) verbal analogies subtest, (3) letter-word identification, and (4), dictation. To be included in the study, participants' CALP scores in English and Spanish had to at least be 3. Thirty-six participants met this criterion, however, data from 1 participant was excluded because of a data recording error, leaving a total analyzable sample of 35. The language with the higher CALP score was considered the L1. Twenty-one participants were English-dominant 14 were Spanish dominant (see Table 2). Participants completed the English Spanish Proficiency and Dominance Assessment (ESPADA) (Francis & Strobach, 2013). All participants reported having learned Spanish earlier than English and reported a greater percentage of time reading in English than in Spanish (see Table 2).

Table 2: Participant language proficiency characteristics of Experiment 1

	English Dominant (*n* = 21)	Spanish Dominant (*n* = 14)
English AoA (years of age)	5.1	6.9
Spanish AoA (years of age)	2.7	1.9

English CALP	4.2	3.5
Spanish CALP	3.7	4.0
Percent time spent reading in English	87	71
Percent time spent reading in Spanish	13	29

1.7.3 Design.

Experiment 1 was based on a 2 language (Spanish, English) X 2 switch (switch, non-switch) X 2 cognate status (cognate, non-cognate) within-subjects design. The dependent variables consisted of mean first fixation durations (FFD), mean gaze durations (GD), and mean total reading times (TRT) from the target word region within the sentences.

1.7.4 Stimuli.

Critical words. Critical words consisted of 60 cognates matched with 60 non-cognate nouns based on CELEX word frequency (Baayen, Piepenbrock, & Gulikers, 1996) and length using the NIM on-line lexical database (Baayen, Piepenbrock, & Gulikers, 1996) (Guasch, Boada, Ferré, & Sánchez-Casas, 2013). The orthographic overlap of the cognates was calculated from MatchCalculator (Davis, 2005) (see Table 3). Cognates tend to be closer in orthographic similarities because most are almost identical in word structure and meaning compared to non-cognate words. Cognates and matched controls were rotated through all possible conditions across four experimental running lists of 120 sentences using a Latin Square design.

Table 3: Lexical characteristics of critical word stimuli

	English Word Length	Spanish Word Length	Word Length Difference	English Word Frequency	Orthographic overlap
Cognate	5.97	6.50	-0.53	16.79	0.63
Non-cognate	5.77	6.68	-0.91	17.91	0.15

Note: Word Frequency is derived from occurrences per million, and are median estimates.

Sentence Stimuli. For each critical word, four sentences were created, one entirely in English, one entirely in Spanish, one with a language switch from English to Spanish, and one with a switch from Spanish to English. Sentences were written such that the meaning of the target word was not strongly biased. (See Table 4 for example sentences). For language switched sentences, the critical cognate and non-cognate nouns were the switch point. The switch always occurred in mid-sentence.

Table 4: Example sentence stimuli used in Experiment 1

Switch type	**Cognate status**	**Example sentence**
English-Spanish	cognate	The two sisters took the tren para visitar a sus, padres.
	noncognate	The brothers went to the piscina a nadar con sus amigos.
Spanish-English	cognate	Las dos hermanas tomaron el train to visit their parents.
	noncognate	Los hermanos fueron al pool to swim with friends.
All English	cognate	The two sisters took the train to visit their parents.
	noncognate	The brothers went to the pool to swim with friends.
All Spanish	cognate	Las dos hermanas tomaron el tren para visitar a sus padres.

noncognate	Los hermanos fueron a la piscina a nadar con sus amigos.

Sentence norming. Participants from the same target population as the critical experiments were recruited for sentence norming procedures. The initial list of sentence stimuli was randomly split into two lists, such that participants rated half the stimuli on predictability and the other half on the naturalness of the switch, the two halves were counterbalanced across participants, so they only normed each sentence once on one attribute. To obtain a measure of predictability of target word, sentences were presented up and to but not including the target word, participants were asked to complete the missing word that followed the first half of the sentence (See Table 5 for prediction probability by condition). Secondly, to get a measure of the naturalness of the switch, participants were presented with the entire code-switched sentence and indicated if the sentence read “normal” or “not normal.”

Table 5: Prediction probability by word condition

Critical word	Mean	SD
Cognate (English)	0.02	0.005
Non-Cognate (English)	0.02	0.005
Cognate (Spanish)	0.01	0.038
Non-Cognate (Spanish)	0.02	0.065

Note: Means are derived from the amount of times raters did predict the word during norming.

1.7.5 Apparatus.

Eye movement data were obtained by using an Eye-Link 1000 tower-mounted system (SR-Research). Stimuli were presented binocularly, and eye movements were recorded from participants' dominant eye. The right eye was used as default if the participant did not know which one of their eyes was the most dominant.

1.7.6 Procedure.

Before testing, participants completed informed consent. Next, participants completed the four subtests of the WMLS-R. Participants who met proficiency criteria were then tested seated in front of a computer screen of the eye-tracker system in an individual testing room. Participants placed their chin on a chin rest and then subjected to a nine-point calibration for accuracy. Participants were then told that they would be presented with sentences in either English or Spanish and that some would contain a language switch. They were also told that true-false questions would follow some sentences.

Each trial started with a fixation point, and participants were to press the spacebar to initiate a trial. Each sentence was presented one at a time in the center of the computer screen. Participants then pressed the spacebar when they were done reading the sentence. To ensure that participants were reading for comprehension, the participants were presented with a true/false question, after every 20 sentences. A drift correct was also placed at the beginning of each sentence to ensure that the participants focused on the sentence that was about to be presented.

After the sentence comprehension task participants completed the ESPADA self-report survey (Francis & Strobach, 2013). Once participants had completed the survey, they were debriefed, thanked for their participation, granted credit, and dismissed. The entire experiment took no more than 2 hours.

1.8 Results.

1.8.1 Approach to analysis.

We constructed Linear Mixed Effects (LME) models using the lme4 library (Bates, Maechler, & Bolker, 2012) within R (RCoreTeam, 2017). Each eye-tracking measure was analyzed in a separate model. All models included cognate status, language switch and the language of the critical word as fixed factors. The random-effects structure of the models included random intercepts and slope adjustments for each fixed factor. Since all three factors are item characteristics, slope adjustments were made by subjects and only random intercepts were included for items. Random effects with high collinearity (>.9) were removed from the model.

1.8.2 First Fixation Duration.

The random slope adjustment for cognate status was removed from this model due to high collinearity. First fixation durations a switch was significantly longer after a language switch, $\beta = 11.4758$, $SE = 3.6991$, $t = 3.102$, $p < .05$. There were no other significant main effects or interactions (all p's > .05)

1.8.3 Gazed Duration.

The random slope adjustment for cognate status and switch were removed from this model due to high collinearity. Gaze durations were significantly longer after a language switch, $\beta = 35.406$, $SE = 6.232$, $t = 5.624$, $p < .05$. There were no other significant main effects or interactions (all p's > .05)

1.8.4 Total Reading Time.

The random slope adjustment for cognate status and switch were removed from this model due to high collinearity. Total reading times were significantly longer after a switch, β =

75.655, *SE* = 7.917, *t* = 9.55 6, *p* < .05. There was no significant impact of word language or sentence type. There were no other significant main effects or interactions (all p's > .05)

1.8.5 Spillover.

The random factors for language switch and language were removed from the model due to high collinearity. Spillover durations were significantly longer after a language switch relative to a non-switch, *β* = 9.556, *SE* = 4.622, *t* = 2.067, *p* = 0.04. There was no significant interaction between switch, word language, and cognate status.

1.8.6 Skip rates.

Skipping rates were significantly higher for cognates (*M* = 6.38, *SD* = 0.25) than for non-cognates (*M* = 4.57, *SD* = 0.21), *β* = -0.415, *SE* = 0.168, *z* = -2.475, *p* = 0.01. Skipping rates were lower for language switches (*M* = 4.43, *SD* = 1.68) relative to non-switches (*M* = 6.53, *SD* = 0.75, *β* = -0.562, *SE* = 0.150, *z* = -3.750, *p* < .05. This was qualified by a significant interaction with the language of the critical word, *β* = 0.680, *SE* = 0.293, *z* = 2.317, *p* < .05. Specifically, skipping rates were higher for L1 words (*M* = 7.05, *SD* = 0.26) relative to L2 words (*M* = 6.00, *SD* = 0.28), in non-switch sentences; whereas the reverse was true for switches, with higher skipping rates for L2 words (*M* = 5.62, *SD* = 0.23), relative to L1 words (*M* = 3.24, *SD* = 0.18) and L2 switched words There were no other significant main effects or interactions (all p's > .05)

1.9 Experiment 1 Discussion.

In Experiment 1 a processing time cost for language-switched words relative to non-switched words was observed across all measures. Critically the effect of the switch cost did not interact with the language of the word or its cognate status. This pattern of results is most consistent with the hypothesis that comprehension of language switches involves activation of a language task schema via a cognitive general control mechanism. If comprehension of switches is guided by cognitive general mechanism, then these should be responsive to non-linguistic cues as well as linguistic information. However, in comprehension, there is rarely a nonlinguistic, reliable cue of a code-switch, instead, the language stimulus itself is the cue. In Experiment 2 we examined whether the presence of nonlinguistic cues attenuates the cost of switching between languages. If costs are attenuated, this suggests that comprehending language switches does involve executive processes outside of the lexicon.

1.10 Experiment 2 Goal.

The goal of the second experiment was to provide a stronger test of the potential role of general executive control processes in language selection by including visual (color) cues of language switches. The general approach consisted of comparing switch costs across three blocks of trials: the first block with no color cues, the second block with color cues and language switches, and a third block that contained color cues without language switches. If a task schema is engaged, then switch costs should be smaller in the color-cued block, particularly midway to the end of the block, relative to the first non-cued block. Also, if language tasks schemas must be inhibited, the switch costs in the third block should be greater than either two of the preceding blocks, particularly in the first half of the block.

1.11 Experiment 2 Method.

1.11.1 Power analysis and sample size.

Similar to Experiment 1, a statistical power analysis was computed using G*Power, and for the present study, 36 participants were needed to detect a medium effect with .87 power (Erdfelder et al., 1996).

1.11.2 Participants.

As in Experiment 1, the participants were Spanish-English bilinguals recruited from the University of Texas at El Paso (UTEP). As in Experiment 1, language dominance was determined based on a higher CALP score obtained from the WLMS-R. Forty-four participants met this criterion, however, data from 4 participants were excluded because of a data recording error, leaving a total analyzable sample of 40. The language with the higher CALP score was considered the L1. Nineteen participants were English-dominant 21 were Spanish dominant (see Table 6). Participants completed the English Spanish Proficiency and Dominance Assessment (ESPADA) (Francis & Strobach, 2013). All participants reported having learned Spanish earlier than English and reported a greater percentage of time reading in English than in Spanish (see Table 6).

Table 6: Participant language proficiency characteristics of Experiment 2

	English Dominant (*n* = 19)	Spanish Dominant (*n* = 21)
English AoA (years of age)	5.1	8.1
Spanish AoA (years of age)	2.4	1.8
English CALP	4.2	3.5
Spanish CALP	3.6	4.1
Percent time spent reading in English	85%	68%

Percent time spent reading in Spanish	15%	32%

1.11.3 Materials and Design.

The second experiment was a 2 language (Spanish, English) X 2 switch (switch, non-switch) X 2 cue (cue, non-cue) within-subjects design. Spanish portions of the sentences were presented in different font colors, either red or blue, counterbalanced across participants.

Critical words. A total of 120 words were selected from Litcofsky & Van Hell (2017). These words were non-cognate nouns. All 120 words were assigned to the four different conditions across eight experimental running lists of 120 sentences using a Latin Square design.

Sentence Stimuli. A total of 120 sentences were selected from Litcofsky & Van Hell (2017). All 120 sentences were assigned to the four different conditions across eight experimental running lists of 120 sentences using a Latin Square design.

Color cueing procedure. Each session was divided into three blocks. The first block served as a baseline, in which sentences did not have any language color cueing. The second block contained switched sentences with one language that was always in one color and the other language in a different color with. The third block consisted of sentences without a switch and the first half was one color and the second half were another color (misleading cue). For example, if the sentence was English first half of the sentence until the target word was in one color and then color was different following the target word. English words were in red-colored font, and the Spanish words were in blue colored font during the cued trials.

1.11.4 Apparatus.

Same as in Experiment 1.

1.11.5 Procedure.

Same as in Experiment 1.

1.12 Results.

1.12.1 Approach to Analysis

As in Experiment 1, eye-movement measures were analyzed through Linear Mixed Effects (LME) models using the lme4 library (Bates, Maechler, & Bolker, 2012) within R (RCoreTeam, 2017). There were three analyses ran for experiment 2 that examined FFD, GD, TRT, spillover, and the skipping rates. The first analysis was run to determine if the presence of a color cue influenced the comprehension of a code switch. Thus, the first set of analysis was run on blocks 1 (no cue) and 2 (cue) for switch trials only, with cue and language of word as fixed factors. The second analysis was run to determine if the color of the font acted as an effective cue for a language switch. Thus, the second model analyzed blocks 1 (no cue) and 3 (misleading cue) across non-switched. The final analysis examined the overall effect of the language switch and the language of the word for the first block only. This analysis was run to examine if the results from experiment 1 replicate in experiment 2. These models included switch condition (switch, no switch) and language of the word as our fixed factors.

1.12.2 The impact of color cue (switched trials only).

1.12.2.1 First Fixation Duration. There were no significant main effects or interactions (all p's > .05)

1.12.2.2 Gazed Duration. There was a significant main effect of color cue, with shorter gaze durations for colored words relative to non-color-cued words, β = 73.310, *SE* =17.770, t = 4.126, $p < .001$. There was a significant main effect of the language of the word, with longer gazed durations for L2 words relative to L1 words, $\beta = 36.610$, $SE = 11.560$, $t = 3.168$, $p < .01$. There were no other significant main effects or interactions (all *p*'s > .05).

1.12.2.3 Total Reading Time. There was a significant main effect of color cue, with shorter gaze durations for colored words relative to non-color-cued words, $\beta = 127.980$, $SE = 25.030$, $t = 5.113$, $p < .001$. There was a significant main effect of the language of the word, where L2 words had longer total reading times than L1 words, $\beta = 55.110$, $SE = 15.720$, $t = 3.531$, $p < .0\ 01$. There were no other significant main effects or interactions (all *p*'s > .05).

1.12.2.4 Spillover. There was a significant main effect of the language of the word, where spillover fixations were longer after L2 words relative to L1 words, $\beta = 19.573$, $SE = 7.236$, $t = 2.705$, $p < .01$. There were no other significant main effects or interactions (all *p*'s > .05).

1.12.2.5 Skip rates. The analyses determined that were no significant main effects or interactions for skip rates (all *p*'s > .05).

1.12.3 The impact of the misleading cue (non-switched trials).

1.12.3.1 First Fixation Duration. In the analysis of non-switched trials, there was a significant main effect of language of the word during on FFD, where L2 words had longer first fixations than L1 words, $\beta = 20.629$, $SE = 5.830$, $t = 3.539$, $p < .001$. There were no other significant main effects or interactions (all *p*'s > .05)

1.12.3.2 Gazed Duration. There was a significant main effect of language of word found on GD, where L2 words had longer gazed durations than L1 words, $\beta = 51.226$, $SE = 17.779$, $t = 2.881$, $p < .01$. There were no other significant main effects or interactions (all *p*'s > .05).

1.12.3.3 Total Reading Time. There was a significant main effect of language of word found on TRT, where L2 words had longer total reading times than L1 words, $\beta = 61.531$, $SE = 17.104$, $t = 3.598$, $p < .001$. There were no other significant main effects or interactions (all p's > .05)

1.12.3.4 Spillover. There were no significant main effects or interactions of spillover on non-switched trials (all p's > .05)

1.12.3.5 Skip rates. There were no significant main effects or interactions of skip rates on non-switched trials (all p's > .05)

1.12.4 The overall effect of language switch and language of the word (Block 1 – no cue).

1.12.4.1 First Fixation Duration. There was a significant main effect of switch, where switched trials had longer first fixations than non-switched trials, $\beta = 25.766$, $SE = 7.478$, $t = 3.445$, $p < .001$. There also was a significant main effect of the language of the words, where L2 words had longer gazed durations than L1 words, $\beta = 15.516$, $SE = 7.527$, $t = 2.061$, $p < .05$. There were no other significant main effects or interactions (all p's > .05)

1.12.4.2 Gazed Duration. There was a significant main effect of switch, where switched trials had longer gazed durations than non-switched trials, $\beta = 112.800$, $SE = 17.230$, $t = 6.548$, $p < .001$. There also was a significant main effect of language of the words, where L2 words had longer gazed durations than L1 words, $\beta = 50.510$, $SE = 18.620$, $t = 2.713$, $p < .01$

There were no other significant main effects or interactions (all p's > .05).

1.12.4.3 Total Reading Time. There was a significant main effect of switch, where switched trials had longer total reading times than non-switched trials, $\beta = 207.090$, $SE = 25.360$, $t = 8.167$, $p < .001$. Secondly, there also was a significant main effect of the language of the words, where L2 words had longer total reading times than L1 words, $\beta = 109.100$, $SE = 30.110$, $t = 3.624$, $p < .001$. There were no other significant main effects or interactions (all p's > .05).

1.12.4.4 Spillover. There were no significant main effects or interactions (all p's > .05).

1.12.4.5 Skip rates. The analyses determined that was a significant effect of skip rates. Specifically, skip rates were significantly higher for non-switched words versus switched words, $\beta = -1.028$, $SE = 0.301$, $z = -3.416$, $p = 0.001$. There were no other significant main effects or interactions for skip rates (all p's > .05).

1.13 Experiment 2 Discussion.

A key finding from Experiment 2 was that processing times of switched words were reduced in the presence of a color cue relative to non-cued switches. This is most consistent with the hypothesis that comprehension of language switches is in part guided by a cognitive-general task switching control mechanism that is sensitive to nonverbal cueing. Therefore, it is possible that central executive processes are not typically engaged in the comprehension of switches, but they might be recruited if task demands encourage their usage.

1.14 General Discussion.

Two experiments investigated the loci of language switches costs during reading comprehension via eye-tracking measurements. In Experiment 1, the objective was to test the alternative hypotheses of global activation, global inhibition and time to lexically retrieve. What we found was a processing time cost for language-switched words relative to non-switched words across all measures. One key finding is that the effect of the switch cost did not interact with the language of the word or its cognate status as predicted earlier.

In Experiment 2, the objective was to provide a stronger test of the potential role of general executive control processes in language selection by including visual (color) cues of language membership. What we found was an overall processing time cost for language-switched words relative to non-switched words across all measures. Another key finding was that there was no interaction between the language of the word or cue. We also found that the switched trials were faster when prompted by a color cue compared to switched trials without the color cue.

Although we found similar results as in previous research, where cognate status did not attenuate the switching costs, we did not find similar patterns when referring to the asymmetrical switch costs in either of our experiments (Bultena, Dijkstra, & van Hell, 2015a, 2015b; Litcofsky & Van Hell, 2017; Wang, 2015). Specifically, we found that there was an overall switch cost in both experiments irrespective of the direction of the language switch, which is most consistent with a task-switching based mechanism. Further evidence of this hypothesis came from Experiment 2 in which a color cue was found to facilitate comprehension of language switched words. Experiment 2 provided converging evidence for this hypothesis These results suggest that a task schema is engaged when switching between languages because there were smaller switch costs in the color-cued block, particularly midway to the end of the block, relative to the first non-cued block. Furthermore, because the switch costs were attenuated during switched trials, it suggests that comprehending language switches does involve executive processes outside of the lexicon as hypothesized in the ICM (Green, 1998; Abutalebi & Green, 2007). Thus, it can be argued that central executive processes not typically engaged in comprehension of switches are recruited if task demands encourage their usage. Therefore, the comprehension of a language switch is guided by the same processes of task switching.

The findings of the present study provide supporting evidence for two loci of switch cost during reading, compared to other models of lexical activation that have implied that lexical activation is solely located within the lexicon. The first locus is within the bilingual lexicon, and this evidence was provided by the overall switch cost in both experiments irrespective of the language. Therefore, non-switched sentences seem to increase the activation, whereas switched sentences contain more interference and seem to decrease activation based on the proper language tag. The second locus of switch cost during reading is at the language task schema level and located outside of the lexicon, in which language task schemas direct activation to entries with the appropriate language tag. This was evident in experiment 2, where we found that the language switch cost was decreased when a non-linguistic color cue was presented during reading. Thus, activation is not solely based on within the lexicon, but on varying levels of activation within and outside the lexicon. This cognitive process is completed by recruiting both lexical and executive control functions based on task demands while reading.

1.15 Conclusion

The findings of the current study provide a firm argument that it is important to highlight that there are two distinct levels at which language switches occur during reading if we are going to explore bilingual speaker's daily usage. Also, further testing that will include levels of proficiency of the bilingual speakers of Spanish and age of acquisition may be warranted to extend the findings of these two experiments. With the large growth of bilingual speakers in the United States, it is volatile to continue to update current models of language switching comprehension, which would, in turn, provide more concrete strategies to help with the educational instruction and assessment of bilingual speakers.

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Vita

Joseph Negron was born in Waukegan, IL. Shortly after his parents moved to Puerto Rico until he was 5 years old, at which his parents returned to Illinois where he was educated until his senior year. Joseph later attended the El Paso Community College where he earned his A.S. in psychology in 2012. After receiving his first degree, he transferred to the University of Texas at El Paso, where he received institutional honors of Cum Laude while completing his B.A. in psychology with a minor in speech language pathology on May 16, 2015. Joseph was accepted into the psychology graduate program in the spring of 2015. He has recently completed his Master's in Experimental Psychology. While in the graduate program he was under the mentorship of Ana I. Schwartz. During his stent in the graduate program he completed his first-year project, worked doing grant evaluation, and taught at the collegiate level as a graduate teaching assistant. Currently, he has taken a position as a special education low-incidence instructor for the Alamogordo Public School District. His plans are to use the teaching experience he received as a graduate student to continue to be successful in his new teaching career. He has completed his Ph.D. course, which he may use later on to receive his doctorate in education.

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