The impact of a momentary language switch on bilingual reading: Intense at the switch but merciful downstream for L2 but not L1 readers

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Abstract

We investigated whether cross-language activation is sensitive to shifting language demands and language experience during first and second language (i.e., L1, L2) reading. Experiment 1 consisted of L1 French – L2 English bilinguals reading in the L2, and Experiment 2 consisted of L1 English - L2 French bilinguals reading in the L1. Both groups read English sentences with target words serving as indices of cross-language activation: cross-language homographs, cognates, and matched language-unique control words. Critically, we manipulated whether English sentences contained a momentary language switch into French before downstream target words. This allowed us to assess the consequences of shifting language demands, both in the moment, and residually following a switch as a function of language experience. Switches into French were associated with a reading cost at the switch site for both L2 and L1 readers. However, downstream cross-language activation was larger following a switch only for L1 readers. These results suggest that cross-language activation is jointly sensitive to momentary shifts in language demands and language experience, likely reflecting different control demands faced by L2 vs. L1 readers, consistent with models of bilingual processing that ascribe a primary role for language control.

Keywords: bilingualism, cross-language activation, reading, language switching

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Bilinguals show unique patterns of reading compared to monolinguals, chiefly due to cross-language activation that occurs even in monolingual contexts. For example, when a French-English bilingual reads the interlingual homographs *chat* in an English sentence, she automatically calls to mind the diverging, feline meaning of *chat* appropriate to the non-target language, French, which slows reading compared to an English-only word form (i.e., a language-unique control word). Alternatively, when the same French-English bilingual reads the cognate word *piano* in an English sentence, which has the same word form and meaning in French, reading is faster compared to a language-unique control word because of lexical and semantic overlap. There is now overwhelming evidence for cross-language activation from the earliest moments of word recognition (for recent reviews see Kroll, Gullifer, & Zirnstein, 2016; Lauro & Schwartz, 2017; Whitford, Pivneva, & Titone, 2016) for interlingual homographs like *chat* (e.g., Dijkstra, Van Jaarsveld, & Ten Brinke, 1998; Libben & Titone, 2009; Pivneva, Mercier, & Titone, 2014; Titone, Libben, Mercier, Whitford, & Pivneva, 2011) and cognates like *piano* (e.g., Gullifer, Kroll, & Dussias, 2013; Hopp, 2016; Libben & Titone, 2009; Pivneva et al., 2014; Titone et al., 2011; Van Hell & Dijkstra, 2002). An open question is whether cross-language activation is sensitive to shifting language demands during bilingual reading, such as a momentary switch into the non-target language. Put concretely, when a French-English bilingual reads the following sentence containing a homograph, "They looked very *soigneusement*, but only a minuscule *dent* was found on each car", does the insertion from French at *soigneusement* (*carefully*) boost the activation of French by the time the reader reaches the downstream homograph target *dent* (meaning *tooth* in French)? Two prevalent models of the bilingual lexicon make predictions regarding the time-course and directionality of these influences on cross-language activation.

The Bilingual Interactive Activation Plus model (BIA+; Dijkstra & Van Heuven, 2002), a connectionist model of bilingual word recognition, assumes that cross-language

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activation arises due to a shared memory store for lexical information in which orthographic, phonological, and semantic representations common to both languages become activated during reading. The model predicts that the magnitude of cross-language activation (from the earliest stages of word recognition) is a function of the baseline level of activation for lexical representations, a factor governed by subjective lexical frequency. Baseline levels of activation are lowest for less frequent representations with low exposure (commonly those in a second language or in a less dominant L1) and highest for more frequent representations with high exposure (commonly those in the native language or in a highly proficient L2). As a result, the model predicts that the magnitude of cross-language activation should be largest for L2 reading, smallest for L1 reading, and should be continuously related to individual differences in language exposure, irrespective of language. Crucially, due to the largely bottom-up nature of BIA+, other factors besides language exposure (such as the language membership of previous words in a sentence or in an experiment) are not predicted to alter the level of cross-language activation during early stages of word recognition. Instead they are predicted to occur only during late stages of word recognition, in a separate task schema after initial word recognition has concluded.

In addition to BIA+, more general models of bilingual language control, such as various instantiations of the inhibitory control model (Abutalebi & Green, 2007; 2016; Green & Abutalebi, 2013), also assume that both languages are activated in parallel. Moreover, control accounts assert that cross-language activation of the L2 and L1 must be actively regulated in a manner that is proportional to the dominance of each language, with the more dominant language (typically the L1) requiring more control for successful suppression than the less dominant language. An issue that has arisen among different versions of the control accounts is the extent to which this regulation occurs at a local level that reflects moment-by-moment processing versus a more global level that reflects cumulative experience of language exposure in different language usage contexts (Abutalebi & Green, 2016; Green & Abutalebi, 2013). Thus, in contrast to BIA+, the class of control models that allows for multiple loci of control (including local, moment-by-moment control) would predict that additional factors besides language exposure could, in principle, aid or impede the regulation of cross-language activation from the earliest moments of word recognition. These factors may include the language membership of previous words in a sentence context or an experiment. In sum, this class of models predicts that cross-language activation is a highly dynamic process that can be controlled or even coordinated in the moment to meet the task at hand (Green & Abutalebi, 2013; Green & Wei, 2014).

The results of bilingual reading studies tend to support the BIA+ model (e.g., Gullifer et al., 2013; Libben & Titone, 2009; Pivneva et al., 2014; Schwartz & Kroll, 2006; Titone et al., 2011; Van Assche, Duyck, Hartsuiker, & Diependaele, 2009; Van Hell & Dijkstra, 2002). Cross-language activation is robust across various bilingual populations, and it is persistent across the time-course of processing. Information about the time-course of cross-language activation is provided by measures of eye-movements during reading. Reading studies support the notion that cross-language activation occurs during the earliest stages of word recognition (indexed by eye-movement measures that include first-pass fixations, such as gaze duration) and persists into late stages into word recognition (indexed by eye-movement measures that include second-pass fixations, such as total reading time; e.g., Libben & Titone, 2009; Pivneva et al., 2014; Titone et al., 2011; Van Assche et al., 2009; for reviews on cross-language activation, see Kroll et al., 2013; 2016; Lauro & Schwartz, 2017; Whitford et al., 2016; but see Hoversten & Traxler, 2016). The magnitude of cross-language activation is indeed related to individual differences in relative language proficiency, with larger magnitudes arising when proficiency in the target language is lower or when exposure to the non-target language is higher (e.g., Pivneva et al., 2014; Titone et al., 2011). Moreover, an individual's degree of L2 exposure has been shown to modulate word frequency effects in both the L1 and L2 (e.g., Whitford & Titone, 2012). However, there is conflicting evidence about whether cross-language activation is sensitive to the demands imposed by the reading task.

Evidence for cross-language activation is observable in completely unilingual situations, such as when participants are recruited and tested entirely in the native language or otherwise remain unaware of the relevance of bilingualism to the experiment (e.g., Van Hell & Dijkstra, 2002; Thierry & Wu, 2004). Moreover, the magnitude of cross-language activation is relatively insensitive to basic sentence context effects, such as the presence of surrounding words entirely in one language (e.g., Gullifer, Kroll, & Dussias, 2013; Libben & Titone, 2009; Schwartz & Kroll, 2006; Van Assche, Drieghe, Duyck, Welvaert, & Hartsuiker, 2010). Thus, it would seem that the presence of cross-language activation is unaffected by task demands that might otherwise signal the target language. At the same time, some evidence suggests that the magnitude of cross-language activation can change over the course of an experimental session or when the semantics of a sentence is highly biased toward the target words, suggesting that under the right circumstances, bilinguals may be able to use information encoded in the task or sentence context to ignore irrelevant lexical representation (e.g., Elston-Güttler, Gunter, & Kotz, 2005; Lauro & Schwartz, 2017; Libben & Titone, 2009; Schwartz & Kroll, 2006). These findings remain generally consistent with BIA+ because the available evidence on the time-course of processing indicates that the modulatory effects occur only during late stages of word recognition (i.e., during total reading time; Pivneva et al., 2014; Titone et al., 2011; Van Assche, Drieghe, Duyck, Welvaert, & Hartsuiker, 2010; but see early modulations in event-related potentials, Elston-Güttler et al., 2005), possibly after an initial decision made by the word recognition system proper.

Therefore, an open question is whether other features of sentence context influence cross-language activation, besides the semantic constraint of a sentence. Here we investigate whether a temporary shift in language mid-sentence, such as a momentary switch or insertion (Green & Wei, 2014; Muysken, 2000) from the non-target language and back, can boost cross-language activation and influence reading downstream at a later point in the sentence. Related effects have been described in a body of literature showing that the presence of words with cross-language overlap, such as homographs or cognates, facilitates cross-language codeswitches (see work on the *triggering hypothesis*; e.g., Broersma & De Bot, 2006; Clyne, 1980; Clyne, 2003; Fricke & Kootstra, 2016; Kootstra, Van Hell, & Dijkstra, 2012; Li & Gollan, 2017; but see Bultena, Dijkstra, & Van Hell, 2015b). Crucially, this facilitation is assumed to occur through heightened cross-language activation at the lexical level (Broersma & De Bot, 2006; Clyne, 2003). Thus, to the extent that this mechanism is generalizable, an overt switch in language should similarly function to trigger heightened cross-language coactivation, giving rise to increased magnitudes of cognate facilitation and homograph inhibition relative to language-unique control words.

A vast body of evidence shows that the exogenous requirement to switch languages during word naming or when reading has consequences for language processing, notably in the form of language switching costs (e.g., Altarriba, Kroll, Sholl, & Rayner, 1996; Bultena, Dijkstra, & Van Hell, 2015a; 2015b; Costa & Santesteban, 2006; Declerck & Philipp, 2015; Gollan & Ferreira, 2009; Litcofsky & Van Hell, 2017; Meuter & Allport, 1999; Wang, 2015; for a review, see Bobb & Wodniecka, 2013). Switch costs in language production, particularly asymmetric switch costs that are larger into the dominant language, are the hallmark evidence for control accounts and are frequently interpreted as evidence for the inhibition of a previously activated non-target language, typically the L1 (e.g., Abutalebi & Green, 2008; Bobb & Wodniecka, 2013; Green, 1998; Gollan, Schotter, Gomez, Murillo, & Rayner, 2014; Meuter & Allport, 1999). At the same time, alternate perspectives cast switch costs in terms of persistent activation of the prior language, and these accounts do not presuppose that inhibition is required to suppress activation of the non-target language (e.g., Philipp, Gade, & Koch, 2007; Verhoef, Roelofs, & Chwilla, 2009).

During reading and comprehension of words within sentences, switch costs are commonly symmetric or asymmetric and larger for a switch into the less dominant language (e.g., Bultena et al., 2015a; 2015b; Proverbio, Leoni, & Zani, 2004), most consistent with a persistent activation perspective. Costs tend to occur at the site of a switch or in spillover regions directly following the switch (e.g., Bultena et al., 2015a; 2015b). The magnitude of observed switch costs is related to several factors including language proficiency (e.g., Bultena et al., 2015a; 2015b), presentation mode (Johns, Valdés Kroff, & Dussias, 2018), and the distributional patterns of language switching as it occurs in the natural environment (Beatty-Martínez & Dussias, 2017; Guzzardo Tamargo, Valdés Kroff, & Dussias, 2016). Few studies have measured for downstream consequences associated with the presence of a prior switch during reading, but the extant research suggests that downstream costs are minimal (Bultena et al., 2015a; 2015b; Gullifer et al., 2013). Moreover, it appears that the requirement to switch languages at a previous point in a sentence has no measurable influence on the magnitude of cross-language activation, at least as measured by the cognate facilitation effect (Gullifer et al., 2013; but see Dijkstra et al., 1998; Dijkstra, De Bruijn, Schriefers, & Ten Brinke, 2000; Titone et al., 2011 for effects of language intermixing on cross-language activation within stimulus list composition). Both of these findings suggest that the consequences of language switching in comprehension, whether related to inhibition or persistent activation of the non-target language, may be quite fleeting.

Here, we examine whether a switch into the non-target language at an initial point in a sentence influences downstream reading, including the magnitude of cross-language activation. To this end, two groups of participants who are bilingual in French and English but acquired their languages in a different order (Experiment 1: L1 French - L2 English bilinguals; Experiment 2: L1 English - L2 French bilinguals) read English sentences while their eye-movements were monitored. Thus, Experiment 1 pertains to L2 bilingual reading, and Experiment 2 pertains to L1 bilingual reading. Half of the sentences were unilingual

English sentences and the other half contained insertions from French at an initial segment of the sentence. Early and late stage eye-movements (gaze duration and total reading time, respectively) at the switched region provide an index of language switching costs. Corresponding eye-movements at a target region provide an index of downstream costs. Furthermore, the words in the downstream target region consisted of French-English homographs, French-English cognates, or lexically-matched English-unique control words, providing an index of the magnitude of cross-language activation. Given that readers might habituate to the presence of codeswitches over the experimental session in a manner that could impact both reading costs at the switch, and also downstream cross-language activation, we also examined interactions of our manipulations with continuous trial order.

If language switching has lasting consequences for downstream reading, then a cost should emerge at the switch site, and should persist downstream to the site of the target word. Crucially, if switching also has consequences for the magnitude of cross-language activation, then homograph and cognate effects should be larger following a prior language switch. Both BIA+ (Dijkstra & Van Heuven, 2002) and control accounts (e.g., Green, 1998; Abutalebi & Green, 2007; 2016; Green & Abutalebi, 2013) predict that cross-language activation depends on language exposure, sentence context effects (i.e., language switching), and task demands (i.e., trial order). However, the two theoretical accounts outlined above make different predictions regarding the time-course and directionality of the influences of language switching on cross-language activation.

First, regarding the time-course of effects, BIA+ predicts that influences of prior sentence context (i.e., whether there was a prior language switch) on cross-language activation should occur only during late stages of word recognition (in total reading time). In contrast, control accounts with multiple loci of language control leave open the possibility for modulations to occur during early stages of word recognition (in gaze duration). Second, regarding the directionality of effects, BIA+ predicts that the magnitude of cross-language activation during should be maximal during L2 reading (due to the high baseline activation of the L1), minimal during L1 reading (due to the low baseline activation of the L2), and generally stable across the course of the task within each language. Crucially, control models predict that the presence of a switch into the L1 during L2 reading should have little consequence for the magnitude of L1 cross-language activation because the L1 is already under tight control. However, the presence of a switch into the L2 during L1 reading may actually trigger L2 cross-language activation because L1 is less demanding with respect to cross-language activation of a weaker L2. A spike in cross-language activation during L1 reading would be counterintuitive from the perspective of BIA+. To foreshadow the results, while both L2 and L1 reading are impacted by a switch in the moment, only L1 reading experiences a lasting disruption, evident as downstream switch costs and a boost in cross-language activation during reading of the later target.

Experiment 1: French L1 – English L2 bilinguals reading in their L2

Method

Participants. We tested 38 bilingual speakers of French and English who identified French as the L1. The participants were from McGill University and the surrounding area (Montréal, Quebec, Canada). All participants gave informed consent, and the study was approved by the Research Ethics Board Office at McGill University. Participants were all proficient bilinguals of French and English. Data for three participants were unavailable due to either excessive track loss ($N = 1$) or other technical issues with calibration during the eye tracking experiment ($N = 2$), resulting in a final sample of 35 participants.

All participants had normal or corrected-to-normal vision and they reported no speech or hearing disorders. Participants completed a language history questionnaire based on the LEAP-Q (Marian, Blumenfeld, & Kaushanskaya, 2007). In this questionnaire, participants reported information related to their age of L2 acquisition, relative exposure to French and English, and their self-rated abilities for French and English. Age of L2 acquisition was determined based on the question "Age when you began acquiring this language" and relative exposure to the L2 was based on the question "Please list what percentage of time you are currently and on average exposure to each language". These data are summarized in Table 1.

Overall, participants were highly accurate in responding to comprehension questions (M: 89%), indicating that they understood the meaning of the sentences.

Materials. The experimental materials were repurposed from a subset of the materials used in (Libben & Titone, 2009). The purpose of that study was to determine how semantic constraints influence cross-language activation. The materials consisted of English sentences that contained sets of English target homograph and cognate words that, relative to control words, probe cross-language activation. Half of the sentences were high semantic constraint (i.e., upcoming words were highly predictable given the context) and the other half were low semantic constraint (i.e., upcoming words were not predictable given the context). Crucially, because past research shows that high semantic constraint sentences reduce cross-language activation (e.g., Lauro & Schwartz, 2017; Libben & Titone, 2009; Schwartz & Kroll, 2006), we selected only the low constraint sentences to maximize the magnitude of co-activation. The target words consisted of 32 French-English homographs, 32 French-English cognates, and 64 English-unique control words that were matched to each of the critical words on the basis of word length, word frequency, and neighborhood density (for a more detailed account of the item characteristics, refer to Libben & Titone, 2009).

We modified each English sentence by adding a language switch into French in an initial region of the sentence. After the switch, the language of the sentence returned to English. This insertion always preceded a target word in the sentence. The majority of switch regions consisted of a single word: an open-class translation equivalent. On the rare occasion that a single word in French could not be naturally substituted for the English word, we used the multi-word translation equivalent (e.g., "en bonne santé" for "healthy").[1] Because the stimuli were repurposed from a previous study, the word class of the switch region was highly variable and included predicate adjectives, adverbs, nouns, and verbs. However, the word type was the same within each switch – nonswitch condition. In addition, the degree of cross-language overlap present in the switch region also varied (e.g., whether the switch was a cognate or language-unique word), though there were no perfectly form-identical word pairs. However, we computed the Levenshtein distance between each translated switch and the original region, normalized on the basis of the region length (i.e., $Norm. Dist. = 1 - (\frac{distance}{length})$). This metric has been successfully used in the classification of cognate stimuli (with a threshold of 0.50; e.g., Schepens, Dijkstra, Grootjen, 2012). Overall, the stimuli had a mean normalized distance of 0.33 (SD: 0.26; range: 0 - 0.89), suggesting that, on average, the words were non-cognates. Approximately one-third of the switch regions had a normalized distance greater than or equal to 0.50, indicative of cognate status. Importantly, the mean normalized distance did not differ between word type conditions for either the cognate stimuli or the homograph stimuli ($M_{Cognate}$: 0.37, $M_{Noncognate}$: 0.35, $M_{Homograph}$: 0.31, $M_{Nonhomograph}$: 0.31, all $t < 1.96$, $p > 0.05$). The mean number of intervening words between the end of the switch region and the beginning of the downstream target region was 3.59, and the number of intervening words did not differ between word type conditions for either the cognate stimuli or the homograph stimuli ($M_{Cognate}$: 3.38, $M_{Noncognate}$: 3.44, $M_{Homograph}$: 3.91, $M_{Nonhomograph}$: 3.62, all $t < 1.96$, $p > 0.05$).

We counterbalanced the sentences into 12 pseudorandomized lists so that a given participant saw each target and matched control word, but never in the same switching condition. Each list contained 13 practice trials, 128 critical trials, and 42 filler trials. Twenty

[1] All statistical models include a fixed effect for the length of the language switch region (in characters) to overcome potential confounds in length.

trials contained comprehension questions. Participants did not receive repetitions of stimuli. See Table 2 for sample items from each condition.

Procedure and apparatus. Participants gave informed consent and then completed the sentence reading task. We instructed participants to read each sentence naturally and silently for comprehension. Participants answered yes/no comprehension questions that occurred on approximately one-tenth of the trials. After the task, participants completed a language history questionnaire and a cognitive battery.

We acquired eye-movement data at a rate of 1000 Hz from the right eye using an Eye-Link 1000 tower mounted system (SR-Research, Ontario, Canada). Sentences were displayed on a 21-inch ViewSonic CRT monitor, positioned 57 centimeters from the participant. We presented sentences on a single line in 14-point monospaced font (i.e., Courier New) using UMass EyeTrack software (downloadable from: https://blogs.umass.edu/eyelab/software/).

Results

Analysis approach. The data were prepared, plotted, and analyzed in R (R Core Team, 2017) using the following packages: *tidyverse* (Wickham, 2017), *lme4* (Bates, Mächler, Bolker, & Walker, 2015), and *effects* (Fox, 2003; Fox & Hong, 2009). Prior to analysis, we removed zero-values from the reading measures. We log-transformed the reading time measures to correct for skew.

We used linear mixed effects regression models on trial-level data to analyze two eye-movement measures: first pass gaze duration, as an indicator of completed early word recognition, and total reading time, as an indicator of completed late stage word recognition. We conducted two sets of analyses focusing on the two critical regions of each sentence: (1) the region in the initial segment of a sentence that either contained a language switch or did not, and (2) the downstream target region that contained either a homograph, a cognate, or an English-unique control word. Thus, the first region provides information about processing of a language switch in the moment and the second region provides information about processing downstream following a switch.

Within each region, we first present *core models* that were designed to provide a conservative test of whether the experimental manipulations elicited an effect that generalized over individual variation among subjects and items (similar to F1 and F2 analyses in repeated measures analysis of variance). For this approach, we included maximal random effects (slopes and intercepts by subjects and items) as supported by the data (e.g., Matuschek, Kliegl, Vasishth, Baayen, & Bates, 2017). In the event a model did not converge, we consecutively removed random slopes until the model did converge, following procedures outlined in Barr, Levy, Scheepers, & Tily (2013). Next, to examine interactions with L2 exposure, we present follow-up models that included additional higher-order interactions with overall percentage of L2 exposure as reported on the language history questionnaire. Because the purpose at this stage of analysis is to explore individual variation of the experimental effects within a fixed-effects analysis, we removed all random slopes for these models (i.e., we used intercept-only models), which would completely capture interesting individual variation related to the exposure variable. In this stage, we only report significant higher-order interactions with L2 exposure to avoid repetition.

The analyses in the switching region included the following predictors: length of the region (as a nuisance variable), whether the region was switched into French (switching: critical switch vs. no switch control), trial order, and the interaction between trial order and switching. We divided the analyses in the downstream target region into those examining the homograph effect (homographs and matched non-homograph controls) and those examining the cognate effect (cognates and matched non-cognate controls). We used separate models for homograph and cognate stimuli to avoid adding unnecessary complexity and because the homograph and cognate materials were not matched to each other. The analyses in the downstream target region included the following fixed effects: length of the previous region (as a nuisance variable), trial order, whether the previous region contained a switch (switching factor: critical switch vs. no switch control), word type (word type factor: critical homograph or critical cognate vs. matched control), and all higher order interactions between trial order, switching, and word type.

All categorical predictors were treated as two-level factors and were sum-coded (critical condition: −0.5 vs. control condition: +0.5). All numerical predictors (i.e., trial order and length of the switch region) were centered and standardized to aid model interpretation. However, to aid visualization we divided trial order into three bins of the experimental session: early, middle, and late.

Significance of beta values were evaluated using Satterthwaite approximations implemented in the *lmerTest* package (Kuznetsova, Brockhoff, & Christensen, 2016). We set the *a priori* significance criterion at the α-level of 0.05 and did not correct for multiple comparisons, two decisions that are standard in research in eye-movements despite the presence of many often-correlated (though theoretically distinct) eye-movement measures (see e.g., Von der Malsburg & Angele, 2017). Recently, and after the analysis of this dataset, Von der Malsburg & Angele raised the point that the ubiquitous failure to correct for multiple comparisons results in false positive rates at “unacceptable levels.” Although we restricted our analyses to only two of the many eye-movement measures (gaze duration and total reading time), and we consider each measure to be a fundamentally different reflection of what is happening in terms of comprehension processes (i.e., gaze duration reflects early lexical activation, total reading time reflects later integrative aspects of lexical processing), it is possible that the multiple comparisons problem is an issue here. At the same time, statistical rigour dictates that the α-level and correction approach be decided before the analyses are conducted. To help address this issue, we maintain an *a priori* α-level of 0.05, but we report exact, uncorrected p-values with exponential notation for very small values. This allows for the application of various correction measures on-the-fly. For example, one might apply the Bonferroni correction by setting the new α-level at 0.05 / 2 (measures).

The data and scripts to reproduce the analyses and figures are available at the Open Science Framework at https://osf.io/gj4qf/.

Language switch region. If language switching from the L2 to the L1 has measurable costs on sentence reading, then there should be significant switching effects in this region, particularly for trials that occur early in the course of the experimental session. If switch costs are dependent on bilingual experience, then there should be higher order interactions between L2 exposure and switching. Figure 1 (upper-left panels) provides an illustration of the subject-aggregate data for the experimental effects of interest (eye-tracking measures and switching) at the language switch region and Table 3 shows conditional means and standard deviations.

Core models. In core gaze duration models, there was a significant effect of region length ($\beta = 0.14$, $SE = 0.02$, $t = 9.01$, $p = 2.38e - 14$), indicating that longer regions had longer gaze durations. There was no effect of trial order ($\beta = -0.02$, $SE = 0.01$, $t = -1.43$, $p = 0.1647$). There was a significant effect of switching ($\beta = 0.17$, $SE = 0.03$, $t = 6.21$, $p = 3.15e - 09$), indicating that switched regions had longer gaze durations than nonswitched regions. There was an interaction between trial order and switching ($\beta = -0.05$, $SE = 0.02$, $t = -2.52$, $p = 0.0126$), such that switch costs were reduced over the course of the experimental session.

In core total reading time models, there was a significant effect of region length ($\beta = 0.20$, $SE = 0.02$, $t = 8.62$, $p = 6.44e - 15$), indicating that longer regions had longer total reading times. There was a significant effect of trial order ($\beta = -0.04$, $SE = 0.02$, $t = -2.51$, $p = 0.0167$), indicating that later trials in the experimental session had shorter total reading times. There was a significant effect of switching ($\beta = 0.21$, $SE = 0.04$, $t = 4.67$, $p = 5.97e - 6$), indicating that switched regions had longer total reading times than nonswitched regions. The interaction between switching and trial order was not significant ($\beta = -0.04$, $SE = 0.02$, $t = -1.64$, $p = 0.1078$).

Interactions with L2 exposure. In gaze duration models, there were no significant interactions with L2 exposure (all $t < 1.96$, $p > 0.05$).

In total reading time models, there were no significant interactions with L2 exposure (all $t < 1.96$, $p > 0.05$).

Downstream target region. If language switching from the L2 to the L1 has lasting consequences for L2 word recognition, then there should be downstream switching effects in this region, particularly for trials that occur early in the course of the experimental session. If the L1 is co-active during L2 reading, then there should be significant homograph and cognate effects in this region. Higher order interactions between trial order, prior switching, L2 exposure, and cognate/homograph effects test the extent to which cross-language activation is sensitive to these other factors.

Homographs. Figure 1 (upper-middle panels) provides an illustration of the subject-aggregate data for the experimental effects of interest for the homograph stimuli (eye-tracking measures, switching, word type) at the downstream target region. Table 4 shows conditional means and standard deviations.

Core models. In core gaze duration models for homographs, there were no significant effects (all $t < 1.96$, $p > 0.05$).

In core total reading time models for homographs, there were no significant effects (all $t < 1.96$, $p > 0.05$). Of note, the effect of word type approached significance ($\beta = -0.09$, $SE = 0.05$, $t = -1.72$, $p = 0.0896$).

Interactions with L2 exposure. In gaze duration models, there were significant interactions with L2 exposure. There was a three-way interaction between switching, trial, and L2 exposure ($\beta = -0.04$, $SE = 0.02$, $t = -1.97$, $p = 0.0480$). Downstream switching effects were larger for participants with less L2 exposure, and for these participants, downstream switching effects were facilitatory at early points of the experimental session and inhibitory towards the end of the experimental session. There was also a three-way interaction between word type, trial, and L2 exposure ($\beta = -0.06$, $SE = 0.02$, $t = -3.02$, $p = 0.0025$). Homograph effects were smaller for participants with more L2 exposure. For participants with less L2 exposure, homograph inhibition gradually became homograph facilitation over the course of the experimental session. See Figure 2 (upper panel) for a partial effects plot of this interaction.

In total reading time models, there was only an interaction between trial order and current exposure ($\beta = -0.03$, $SE = 0.01$, $t = -2.05$, $p = 0.04006$).

Cognates. Figure 1 (upper-right panels) provides an illustration of the subject-aggregate data for the experimental effects of interest for the cognate stimuli (eye-tracking measures, switching, word type) at the downstream target region. Table 4 shows conditional means and standard deviations.

Core models. In core gaze duration models for cognates, there was a significant effect of length of the previous region ($\beta = 0.03$, $SE = 0.01$, $t = 2.41$, $p = 0.0185$), indicating that longer regions had longer gaze durations. There was also an effect of word type ($\beta = 0.05$, $SE = 0.02$, $t = 2.19$, $p = 0.0329$), indicating that cognate words had shorter gaze durations than controls. No other main effects or interactions were significant (including the crucial interaction between switching and word type; all $t < 1.96$, $p > 0.05$).

In core total reading time models for cognates, there was a significant effect of word type ($\beta = 0.08$, $SE = 0.03$, $t = 2.32$, $p = 0.0238$), indicating that cognates were read more quickly than controls. No other main effects or interactions were significant (including the crucial interaction between switching and word type; all $t < 1.96$, $p > 0.05$).

Interactions with L2 exposure. In gaze duration models, there were significant interactions with L2 exposure. There was a two-way interaction between word type and L2 exposure ($\beta = -0.04$, $SE = 0.01$, $t = -2.60$, $p = 0.00927$), indicating that cognate effects were larger for participants with less L2 exposure. See Figure 3 (upper panel) for an illustration of this interaction

In total reading time models, there were significant interactions with L2 exposure. There was a two-way interaction between switching and L2 exposure ($\beta = -0.04$, $SE = 0.02$, $t = -2.05$, $p = 0.03983$), indicating that downstream switching effects tended towards facilitation when L2 exposure was high, but inhibition when L2 exposure was low. There was also an interaction between word type and L2 exposure ($\beta = -0.05$, $SE = 0.02$, $t = -2.94$, $p = 0.00326$), indicating that the magnitude of the cognate effect was larger for participants with less L2 exposure. See Figure 3 (lower panel) for an illustration of this interaction.

Summary of results. For French-English bilinguals reading in the L2, we found the following results. At the language switch region, core models showed that there was robust evidence for a cost associated with a switch into the L1 in gaze duration and total reading time, and the cost tended to decrease over the course of the experimental session (in gaze duration). The magnitude of the switch cost did not depend on L2 exposure. At the target region, there was only limited evidence for downstream effects related to a prior switch into the L1. Core models showed no influence of a prior switch, though there was some evidence for switch costs when L2 exposure was low from gaze duration in homograph stimuli and total reading time for cognate stimuli. For homograph stimuli, these costs compounded over the course of the task.

At the downstream region, there was evidence for cross-language activation of the L1. Core models showed a marginal homograph inhibition effect in total reading time and significant cognate facilitation effects in both gaze duration and total reading time. There was also evidence that the magnitude of cross-language activation depended on L2 exposure and trial order. Participants with less L2 exposure showed evidence for homograph effects in gaze duration (but there were no interactions in total reading time). Participants with less L2 exposure also showed larger cognate effects in gaze duration and total reading time. Overall, participants with more L2 exposure generally exhibited smaller cross-language effects.

The observation that cross-language effects were largest for participants with less exposure to the L2 is consistent with predictions made by the BIA+ model. Crucially, there were no interactions between the magnitude of cross-language activation and whether a sentence contained a prior switch into the L1. This result is thus far consistent with BIA+ because it predicts that factors outside language exposure should have minimal influences on the degree of cross-language activation during early word recognition. In line with this prediction, the presence of a prior switch did not modulate cross-language activation for either early or late stages of word recognition (measured by gaze duration and total reading time, respectively).

In Experiment 2, we report data from the same task conducted with a group of English-French bilinguals reading in their L1. Here, we again expect a cost at the site of the switch. For the downstream region, if the predictions of BIA+ hold true, then there may be less evidence of cross-language activation in the L1 vs. the L2 due to higher baseline levels of activation for the L1, though cross-language activation should still be related to L2 exposure. The model again predicts minimal influences of task demands (i.e., trial order) and downstream costs associated with a previous language switch during early stages of word recognition (measured by gaze duration). Alternatively, control accounts predict that an insertion from the L2 may require an L1 reader to momentarily down-regulate the L1, causing downstream consequences for reading upon returning to the L1. In this case, down-regulation of L1 may be observable as a residual switch costs and may also reveal greater cross-language activation of the L2.

Experiment 2: English L1 bilinguals reading in their L1

Method

Participants. We tested 42 bilingual speakers of English and French who identified English as the L1. The recruitment procedure was the same as for Experiment 1. Participant characteristics are summarized in Table 1.

Overall participants were highly accurate on the comprehension questions ($M = 96\%$).

Materials. The experimental materials were the same as in Experiment 1.

Procedure and apparatus. The procedure and apparatus were the same as in Experiment 1.

Results

Analysis approach. The analysis routines were the same as in Experiment 1.

Language switch region. If language switching from the L1 to the L2 has measurable costs within sentence context, then there should be significant switching effects in this region. If switch costs are dependent on bilingual experience, then there should be higher order interactions between L2 exposure and switching. Figure 1 (lower-left panels) provides an illustration of the subject-aggregate data for the experimental effects of interest (eye-tracking measures and switching) at the language switch region. Table 3 shows conditional means and standard deviations.

Core models. In core gaze duration models, there was a significant effect of region length ($\beta = 0.14, SE = 0.01, t = 10.71, p = 2e - 16$), indicating that longer regions had longer gaze durations. There was also a significant effect of switching ($\beta = 0.22, SE = 0.03,$ $t = 7.99, p = 2.2e - 12$), indicating that switched regions had longer gaze durations than nonswitched regions. No other main effects or interactions were significant (all $t < 1.96, p > 0.05$), though the interaction between switching and trial order approached the criterion for significance ($\beta = -0.03, SE = 0.02, t = -1.92, p = 0.0607$).

In core total reading time models, there was a significant effect of region length ($\beta = 0.20, SE = 0.02, t = 9.76, p = 2e - 16$), indicating that longer regions had longer total reading times. There was an effect of trial order ($\beta = -0.04, SE = 0.01, t = -3.81, p = 0.000546$), indicating that later trials in the experiment had shorter total reading times. There was also a significant effect of switching ($\beta = 0.36, SE = 0.04, t = 8.01, p = 2.1e - 13$), indicating that switched regions had longer total reading times than nonswitched regions.

There was also an interaction between switching and trial order ($\beta = -0.06$, $SE = 0.02$, $t = -3.70$, $p = 0.000211$), indicating that switching effects decreased over the course of the experimental session. See Figure 4 (lower panel) for an illustration of this interaction.

Interactions with L2 exposure. In gaze duration models, there were no significant interactions with L2 exposure (all $t < 1.96$, $p > 0.05$).

In total reading time models, there was only an interaction between trial order and current exposure ($\beta = 0.03$, $SE = 0.01$, $t = 2.62$, $p = 0.008033$).

Downstream target region. If language switching from the L1 to the L2 has lasting consequences for L1 word recognition, then there should be downstream switching effects in this region. If the L2 is co-active during L1 reading, then there should be significant homograph and cognate effects in this region. Higher order interactions between trial order, prior switching, L2 exposure, and cognate/homograph effects test the extent to which cross-language activation is sensitive to these other factors.

Homographs. Figure 1 (lower-middle panels) provides an illustration of the subject-aggregate data for the experimental effects of interest for the homograph stimuli (eye-tracking measures, switching, word type) at the downstream target region. Table 4 shows conditional means and standard deviations.

Core models. In core gaze duration models for homographs, there were no significant effects (all $t < 1.96$, $p > 0.05$).

In core total reading time models for homographs, there was an effect of trial order ($\beta = -0.05$, $SE = 0.01$, $t = -3.79$, $p = 0.000369$), indicating that later trials were read more quickly. There was an effect of switching ($\beta = -0.06$, $SE = 0.03$, $t = -2.00$, $p = 0.049638$), indicating that downstream effects of switching facilitated total reading times. Crucially, there was also an interaction between switching and word type ($\beta = -0.10$, $SE = 0.05$, $t = -2.23$, $p = 0.028857$), indicating that homograph effects were larger after a prior switch than when there was no switch. This two-way interaction was qualified by a three-way interaction with trial order ($\beta = -0.09, SE = 0.04, t = -2.09, p = 0.036671$), indicating that the magnitude of the homograph effect in the switch condition increased over the course of the experimental session. See Figure 5 (lower panel) for an illustration of this interaction.

Interactions with L2 exposure. In gaze duration models, there was an interaction between trial order and L2 exposure ($\beta = 0.03, SE = 0.01, t = 2.92, p = 0.00354$).

In total reading time models, there were no significant interactions with L2 exposure (all $t < 1.96, p > 0.05$).

Cognates. Figure 1 (lower-right panels) provides an illustration of the subject-aggregate data for the experimental effects of interest for the cognate stimuli (eye-tracking measures, switching, word type) at the downstream target region. Table 4 shows conditional means and standard deviations.

Core models. In core gaze duration models for cognates, there was an effect of trial order ($\beta = -0.02, SE = 0.01, t = -3.24, p = 0.00121$), such that later trials had smaller gaze durations. No other main effects or interactions were significant (including the crucial interaction between switching and word type; all $t < 1.96, p > 0.05$)

In core total reading time models for cognates, there was an effect of trial order ($\beta = -0.04, SE = 0.01, t = -3.70, p = 0.000779$), such that later trials had smaller total reading times. No other main effects or interactions were significant (including the crucial interaction between switching and word type; all $t < 1.96, p > 0.05$)

Interactions with L2 exposure. In gaze duration models, there was an interaction between switching and L2 exposure ($\beta = 0.04, SE = 0.02, t = 2.19, p = 0.0286$), indicating that switches were more costly for participants with more L2 exposure.

In total reading time models, there was an interaction between switching and L2 exposure ($\beta = 0.06, SE = 0.02, t = 2.91, p = 0.003598$), indicating that switches were more costly for participants with more L2 exposure.

Summary of results. For English-French bilinguals reading in their L1, we found the following results. At the language switch region, there was robust evidence for a switch cost when the sentence switched into the L2, and the cost decreased over the course of the experimental session (marginal in gaze duration and significant in total reading time). The magnitude of the switch cost did not depend on L2 exposure. At the target region, there was reliable evidence for effects related to a prior switch into the L2. Core models for homograph stimuli showed a robust 3-way interaction between switching, word type, and trial order in total reading time, an effect that did not depend on L2 exposure. While effects of switching were not present for cognate stimuli, there was an interaction between switching and L2 exposure, suggesting that switch costs were higher for participants with more L2 exposure.

In the target region for L1 reading, cross-language activation was overall minimal. Crucially, there was a significant interaction between the magnitude of the homograph effect and whether the sentence previously contained a switch. Homograph inhibition was only significant following a language switch, and this effect was magnified at the end of the experimental session relative to the beginning. These results suggest that for reading in the L1, the magnitude of cross-language semantic competition of the L2 is sensitive to momentary perturbations introduced by a prior switch into the L2 observable in the eye-movement measure that reflects late stage semantic integration. They also suggest that the consequences of these perturbations accumulate over the course of the experimental session.

Discussion

The purpose of these two experiments was to address whether cross-language activation during bilingual reading is sensitive to differences in language experience among bilinguals (such as the current exposure to the L2) and, crucially, to shifting language demands (such as a momentary shift in the language of the sentence). In line with the BIA+ model of word recognition (Dijkstra & Van Heuven, 2002) and many previous empirical studies (e.g., Gullifer et al., 2013; Hopp, 2016; Lauro & Schwartz, 2017; Libben & Titone, 2009; Pivneva et al., 2014; Titone et al., 2011; Van Hell & Dijkstra, 2002), we observed cross-language activation when French-English bilinguals read words within the context of sentences in their L2. Also in line with BIA+, evidence for cross-language activation was qualitatively much weaker when English-French bilinguals read in their L1. Crucially, in contrast with BIA+ but in line with general models of bilingual language control (Abutalebi & Green, 2007; 2016; Green & Abutalebi, 2013), cross-language activation of the L2 was significant during L1 reading, but only following a prior switch into the L2. This suggests that the control demands placed on the system by a switch into the second language may have required bilinguals to suppress the semantics of the L1, allowing for greater cross-language activation of the L2 downstream from a switch. We discuss each of these findings in turn.

During L2 reading (Experiment 1) at the downstream target region, we observed evidence of cross-language activation at the level of the word form. Specifically, there was some evidence for homograph effects (in gaze duration when accounting for L2 exposure) and robust evidence for cognate facilitation (in gaze duration and total reading time in core models), suggesting that aspects of lexical form representations of the L1 are activated and influence reading in the target language despite the presence of surrounding sentential information that could theoretically be used to control the non-target language (Green, 1998; Abutalebi & Green, 2007; 2016; Green & Abutalebi, 2013). At the same time, the absence of significant homograph inhibition during late eye-movement measures suggests that the semantic representations of the L1 were either not sufficiently co-activated to compete for selection during semantic integration or that they were co-activated but suppressed via language control mechanisms. Importantly, there were further dependencies between cross-language activation during L2 reading, L2 exposure, and trial order.

The magnitude of cross-language activation depended qualitatively and quantitatively on L2 exposure, in line with the BIA+ model that assumes baseline levels of activation are higher for representations in the dominant language (Dijkstra & Van Heuven, 2002). Cross-language activation of dominant L1 word forms was present and robust for French-English bilinguals reading in their L2 (Experiment 1), suggesting that the baseline level of activation for the L1 was sufficiently high to influence L2 reading. However, cross-language activation of the weaker L2 word forms was mostly absent for English-French bilinguals reading in their L1 (Experiment 2), suggesting that the level of L2 activation was not sufficient to overcome the automaticity associated with native language reading. Quantitatively, L2 exposure interacted with the magnitude of cross-language word form activation during L2 reading; cross-language effects were generally largest when L2 exposure was low. However, L2 exposure did not interact with indices of cross-language activation during L1 reading. Together, these results suggest that automaticity conferred by high L2 exposure to L2 reading may also result in decreased cross-language activation of the L1 word forms. However, during L1 reading the baseline level of activation, even among participants with high L2 exposure, may not have been sufficient to influence cross-language activation of the L2 during L1 reading in the present sample of participants.

Exposure-dependent cross-language activation is consistent with other studies of bilingual reading (Libben & Titone, 2009; Pivneva et al., 2014; Titone et al., 2011), though there are notable differences. For the group reading in the L2 (Experiment 1), we observed stronger evidence for this relationship than in previous studies (Pivneva et al., 2014). Here, the interaction occurred for homograph and cognate materials, whereas in previous studies the interactions were significant only for cognate materials (Pivneva et al., 2014). Curiously, for the group reading in their L1 (Experiment 2), we observed no evidence for a relationship between L2 exposure and cross-language activation, somewhat in contrast to previous studies (Titone et al., 2011). Titone et al. (2011) observed interactions between cross-language activation and L2 age of acquisition, a variable that is typically correlated with L2 exposure, in L1 sentences. The magnitude of cross-language activation (via cognate facilitation) was greater for bilinguals with earlier L2 exposure vs. later L2 exposure. In a *post hoc* analysis we tested whether L2 age of acquisition interacted cross-language effects during L1 reading, but there were no significant interactions. While these results differ from those of Titone et al. (2011), they do suggest that factors related to cumulative language experience across the lifespan may relate to baseline activation with respect to the L2.

We further observed that there were consequences related to shifting language demands within a sentence during reading. When a sentence contained an insertion from French, there were robust costs at the site of the switch relative to non-switched sentences. Initial switch costs occurred for both participants reading in their L2 (Experiment 1) and those reading in their L1 (Experiment 2). This finding is in line with many previous studies demonstrating that language switching is associated with a measurable processing cost due to demands associated with suppressing the non-target language or reactivating the target language in the face of persistent activation from the previous language (Bobb & Wodniecka, 2013; Bultena et al., 2015a; 2015b; Declerck & Philipp, 2015; Gollan, Schotter, Gomez, Murillo, & Rayner, 2014; Philipp, Gade, & Koch, 2007; Litcofsky & Van Hell, 2017; Meuter & Allport, 1999; Verhoef, Roelofs, & Chwilla, 2009; Wang, 2009). In our data, switch costs continued to influence downstream processing at a later point in the sentence, particularly in relation to the magnitude of cross-language activation measured by homograph effects. Crucially, this downstream effect was most evident for L1 reading as opposed to L2 reading.

For French-English bilinguals reading in the L2 (Experiment 1), switching effects at the site of the switch did not depend on language exposure. However, downstream costs did depend on exposure. For bilinguals with high L2 exposure, downstream costs at the target region were small or nonexistent. In contrast, bilinguals with less L2 exposure continued to experience downstream costs at the target region. In other words, during L2 reading French-English bilinguals with high L2 exposure were able to quickly regain control of the L2 (English) following a switch into the L1 (French) whereas bilinguals with less exposure struggled to do so.

Similarly, for English-French bilinguals reading in the L1 (Experiment 2), the initial switch cost was not related to L2 exposure. Downstream switching costs were generally minimal but were larger for bilinguals with more exposure. This suggests that bilingual readers can quickly recover from the presence of the L2 during highly automatic L1 reading, unless exposure is sufficiently high in the L2. Crucially, for this group of participants, there was also an interaction between the cross-language homograph effect and whether the previous segment of the sentence contained a language switch. Recall that English-French bilinguals reading in the L1 displayed minimal evidence for cross-language activation of the L2. However, when these participants encountered a language switch into the L2, inhibitory homograph effects were robust in core models. This interaction effect occurred primarily late in the time-course of processing (total reading time measures), suggesting that cross-language activation occurred at the level of the semantics through meaning competition of the homograph words. This finding suggests that insertions from the L2 perturbed otherwise automatic L1 reading, potentially through a combination of triggering persistent cross-language activation of the L2 (e.g., Broersma & De Bot, 2006; Clyne, 1980; Philipp et al., 2007; Verhoef et al., 2009) and L1 suppression (e.g., Green, 1998).

One aspect of the data requires specific mention. A careful observer will note that the homograph effect during L1 reading following a switch is driven by facilitation of the control item, not through a decrease in reading time for the homograph. This is unexpected, as triggered cross-language activation of the L2 should, ostensibly, be evident on the homograph word that contains conflict with the L2. However, we believe that the observation of facilitation may be related to a successful recovery from an earlier L2 switch that is observable in the homograph stimuli which tended to be short and highly frequent words in the dominant L1. Moreover, the facilitation allows for the revelation of cross-language semantic competition from the L2 meaning of the homograph. This observation is most in line with control accounts because they assume that minimal control must be applied during L1 reading due high automaticity. If our L1 readers had been actively controlling L2 activation, then we would not have expected the observed facilitation from the switch.

The observation that the presence of a prior switch interacted with the magnitude of cross-language activation during L1 reading but not during L2 reading is reminiscent of reverse asymmetries in the language switching literature (e.g., Meuter & Allport, 1999). This observation is most consistent with perspectives of bilingual language control and language switching that implicate an inhibitory mechanism (Abutalebi & Green, 2008; Bobb & Wodniecka, 2013; Green, 1998; Gollan, Schotter, Gomez, Murillo, & Rayner, 2014; Meuter & Allport, 1999). For example, Gollan et al. (2014) showed that when bilinguals were required to read and repeat paragraphs that contain "haphazard" language switches, they produced more non-target language intrusion errors relative to single-language paragraphs, suggesting that the requirement to juggle both languages resulted in more failures in language control. Interestingly, Gollan and colleagues found more intrusions for productions in the dominant language relative to the less dominant language, suggesting that the bilinguals were less successful in a situation where they had to inhibit the weaker language to produce the dominant language.

Recent studies on theoretical accounts of codeswitching and its relation to bilingual language control note the importance of assessing group-level and individual-level differences with respect to codeswitching expertise in determining processing of codeswitched stimuli and in shaping executive control processes. For example, the distributional patterns of codeswitches in the natural environment and the degree to which participants engage in codeswitching both contribute to the magnitude of observed language switching costs (e.g., Beatty-Martínez & Dussias, 2017; Guzzardo Tamargo et al., 2016), and individuals who frequently engage in dense codeswitching are predicted to exhibit less competition between the two languages relative to those who do not (Green & Abutalebi, 2013; Green & Wei, 2014). Thus, the extent to which our stimuli varied with respect to distributional patterns of usage or our participants varied with respect to engagement in dense codeswitching could have impacted our results. For example, if our participants did not routinely engage in dense codeswitching, it is possible that they operated in a control mode where the two language are in competition with one another and the non-target language must be suppressed, leading to the present pattern of results. In contrast, participants with a more open mode of control may have shown more evidence of cross-language activation overall, or more sensitivity to the presence of language switches. Although stimulus creation for the present study proceeded in a manner such that all language switches sounded natural, we do not have detailed information regarding distributional patterns nor participants' self-reported engagement in codeswitching. Thus, future research in this area should more closely examine the impact of code-switching behavior.

Another potential caveat related to our results is that we did not explicitly control the degree of cross-language overlap in the switch region. Thus, not all switches may have been equally salient to the reader. For example, a switch with a high degree of form overlap between the two languages such as “Having undergone multiple *révisions* (revisions)...” may exhibit a smaller switch cost compared to “While she was cleaning her *maison* (house)…” and this may also have influenced downstream processing (including the magnitude of cross-language activation). To assess this hypothesis, we performed *post hoc* follow-up analyses where we added higher order interactions with the measure of normalized Levenshtein distance (a measure of form similarity) between each switch and non-switch translation in all core models. In both experiments at the site of the switch, greater form overlap was related to a decrease in gaze duration and total reading times but there was no interaction with the switching effect (which remained significant). This suggests that cross-language form similarity facilitated reading, but not differentially for what we classified as a switch or a non-switch. For downstream reading, there was no indication of any interactions between the distance measure and other factors in either experiment, though there was a main effect of the distance measure for L2 reading (Experiment 1) gaze durations in homograph stimuli, suggesting that greater form similarity slowed downstream reading in this early eye-movement measure. Moreover, the main pattern of results in both Experiments did not change, suggesting that the "magnitude" of the switch did not affect downstream reading. These results are generally in line with BIA+ because form overlap resulted in facilitated processing but not the magnitude of the switch cost either at the switch site or in the downstream target region.

The observation of downstream switch costs and of the interaction between switching and an indicator of cross-language activation is inconsistent with previous studies on language switching in sentence context (e.g., Bultena et al., 2015a; 2015b; Gullifer et al., 2013). These studies find no evidence for downstream costs related to intersentential language switching (language switching between sentences or discourse contexts) and no evidence that a shift in the language of the sentence context modulated cross-language cognate effects. A potential interpretation of those results is that in order for language switching to impact cross-language activation during comprehension, the switch should occur within the same sentence (intrasententially). The results here partially support this interpretation, at least for reading in the L1 where the presence of a switch into the L2 within the same sentence impacted the magnitude of the homograph effect. Importantly, the vast majority of the insertions in the present study occurred at a major clause boundary apart from the downstream target region. Thus, the switches here may be more comparable to intersentential switches and may have resulted in reduced downstream costs relative to a switch within the same clause. If switches had occurred in the same clause as the target region, it is possible we would have observed robust effects for reading in the L2 as well. Future work should explicitly manipulate this factor in a controlled manner to assess whether switches that occur more proximal to the target region result in larger modulatory effects for cross-language activation.

The results presented here are consistent with studies demonstrating that various types of sentential context influence the magnitude of cross-language activation (Lauro & Schwartz, 2017; Libben & Titone, 2009; e.g., Schwartz & Kroll, 2006). The observation that the magnitude of cross-language activation depends on the presence of a previous language switch is somewhat inconsistent with BIA+. While the modulation occurred during late stages of word recognition, in line with BIA+, it is curious that the modulation occurred during L1 reading but not L2 reading. If anything, BIA+ would predict that L2 reading should be influenced by such modulations because of lower baseline levels of L2 relative to L1 activation. In contrast, these results are consistent with control accounts, such as the inhibitory control model (Abutalebi & Green, 2007; 2016; Green & Abutalebi, 2013). These accounts predict that the L1 is actively controlled during L2 use. As such, the application of inhibitory control to the L1 (a frequent occurrence for bilinguals) following a switch into the L1 should allow bilinguals to quickly regain control of the L2, resulting in minimal downstream costs. However, L1 reading may experience a disruption if inhibitory control was previously applied to accommodate a prior switch into the L2. Thus, L2 readers may be better equipped to handle momentary disturbances (such as a switch into the other language) relative to L1 readers because they habitually engage control over the L1 during L2 reading.

Conclusion

We show that the L1 is co-active during L2 reading, but the magnitude of this co-activation is relatively independent of momentary perturbations introduced by a switch into the L1 within the same sentence. In contrast, cross-language activation of the L2 during L1 reading, while minimal, is temporarily increased following a prior switch into the L2. These results suggest that readers are consistently and efficiently able to apply control resources to resolve momentary perturbations caused by the presence of the unintended language in the L2 but may be less able to do so during reading in the L1. Future work should investigate the extent to which the interactions examined here depend on the social or interactional context of language usage. Recent instantiations of bilingual language control models, such as the adaptive control hypothesis (Green & Abutalebi, 2013), predict that the context of language usage drives the configuration of control processes that bilinguals recruit to cope with cross-language activation.

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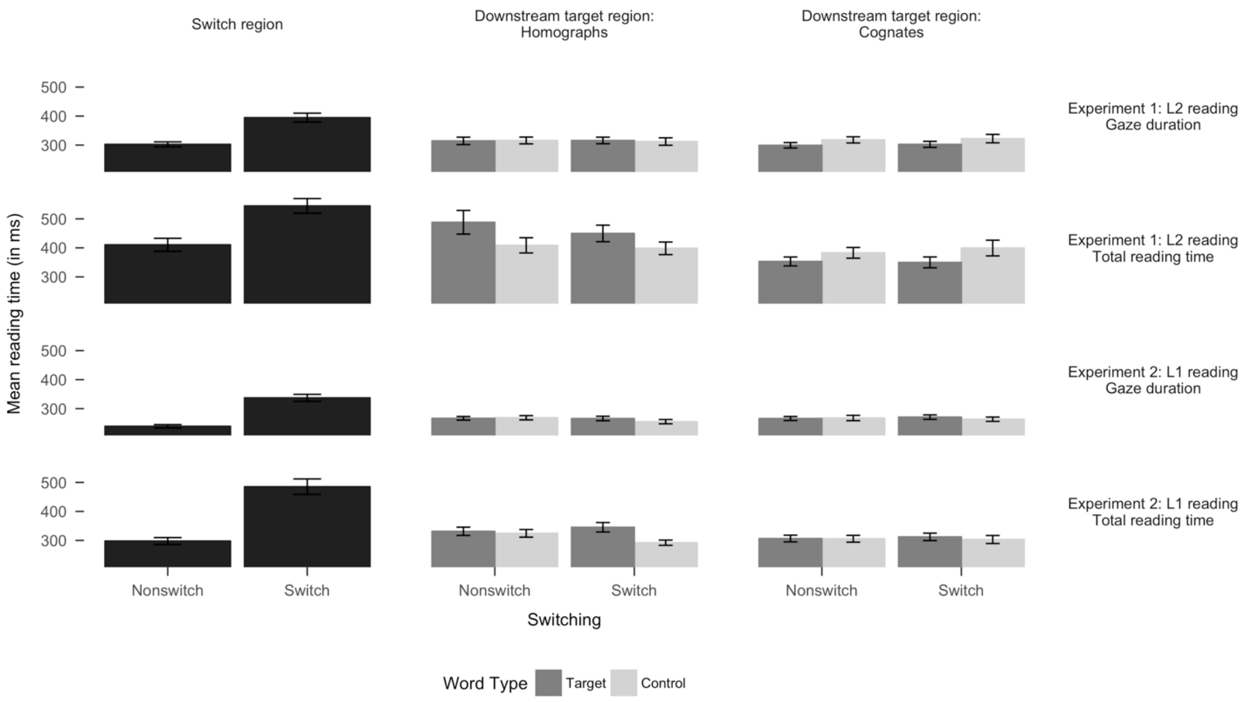

Figure 1. Data from Experiment 1 (L2 reading, upper panels) and Experiment 2 (L1 reading, lower panels) showing the effects of interest (switching, homograph effects, and cognate effects) in each region (switch region and downstream region) for each eye-movement measure (gaze duration and total reading time). For L1 readers, cross-language homograph effects were minimal, but were larger following a switch in total reading times. Error bars depict ±1 *SEM*.

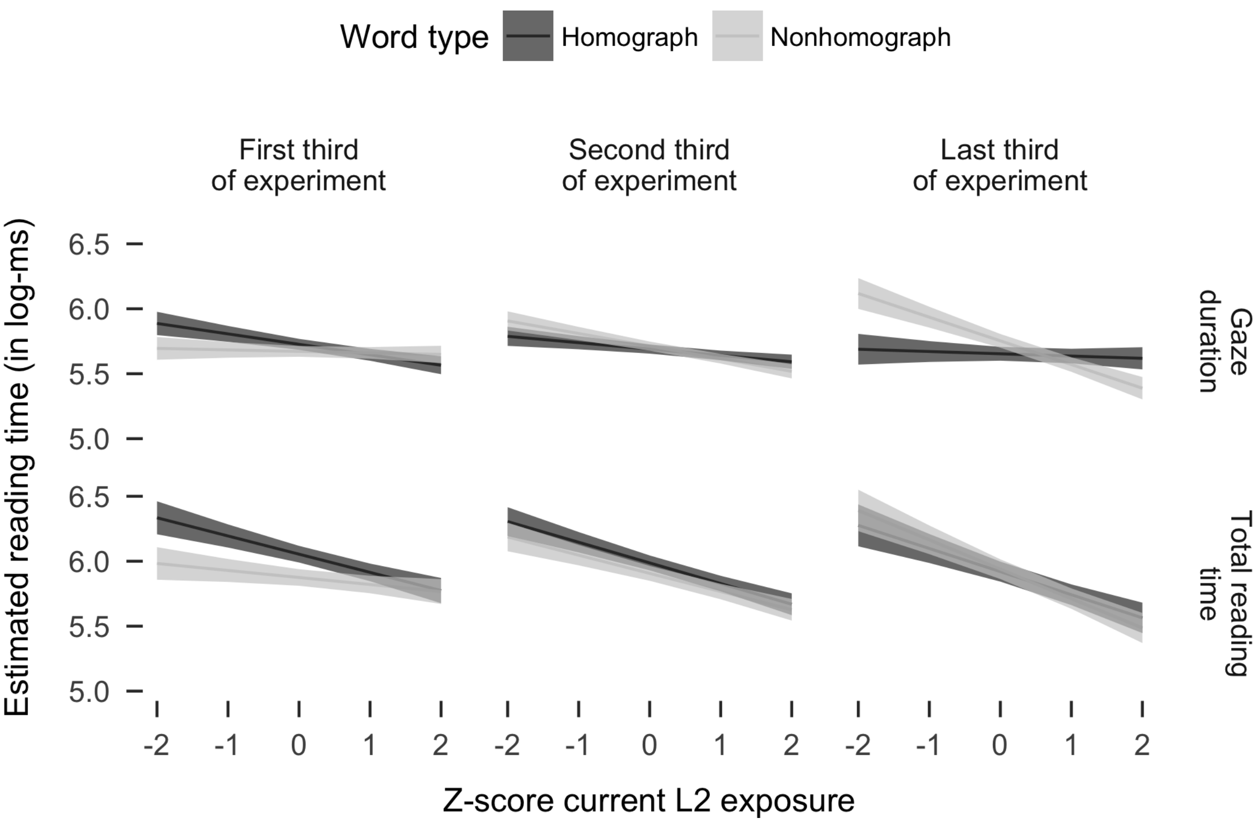

Figure 2. French - English bilinguals reading in L2 (Experiment 1) at the downstream target region. Model-predicted log gaze durations for the homograph by L2 exposure by trial order interaction. Error bands depict ±1 *SEM*. Note: this interaction was significant in gaze duration. It was not significant in total reading time.

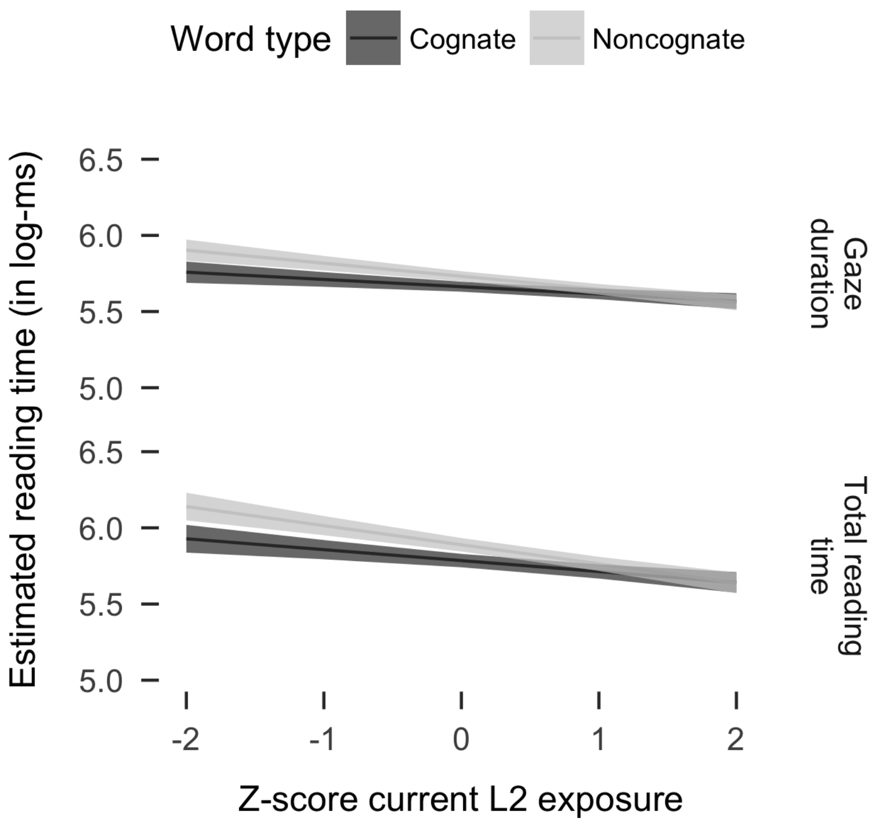

Figure 3. French - English bilinguals reading in L2 (Experiment 1) at the downstream target region. Model-predicted log reading times for the significant cognate by L2 exposure interaction. Error bands depict ±1 *SEM*. Note: this interaction was significant in gaze duration and total reading time.

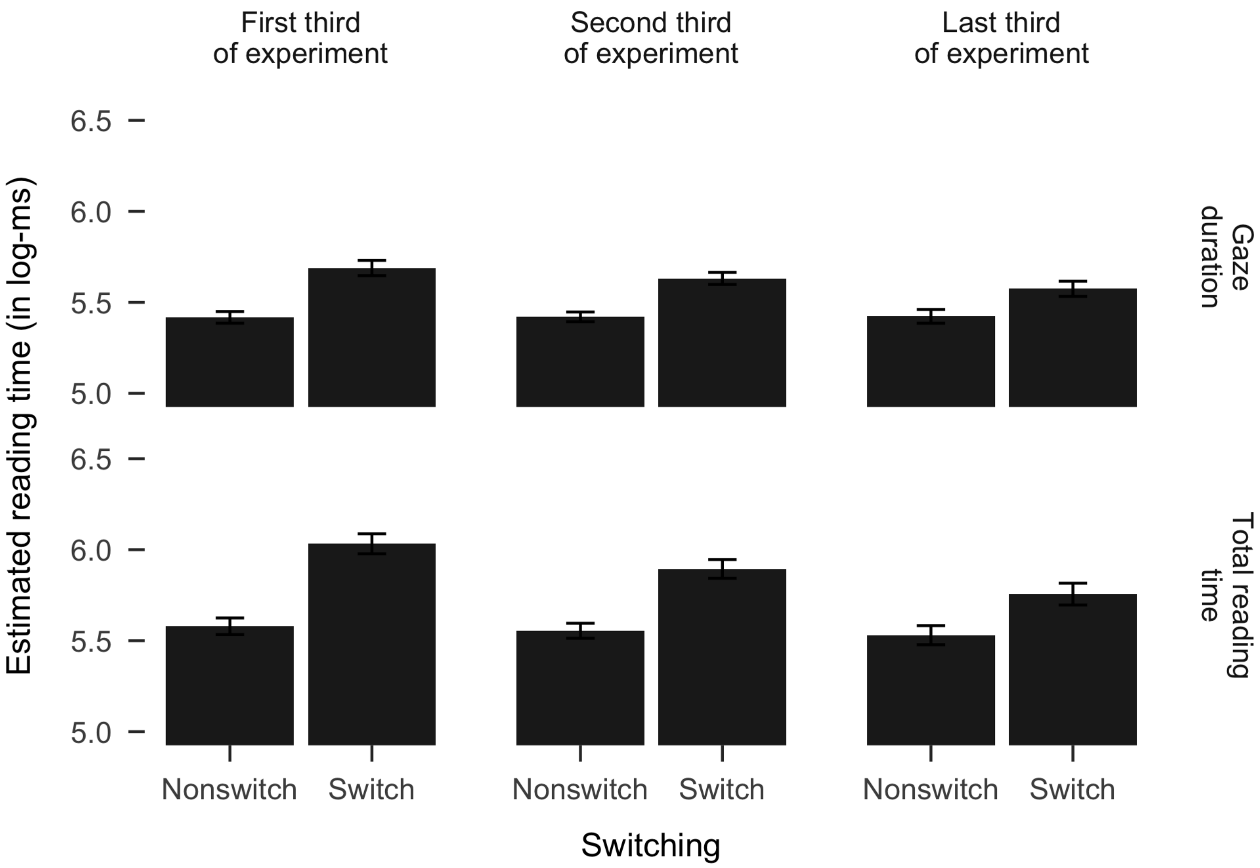

Figure 4. English - French bilinguals reading in L1 (Experiment 2) at the language switch region. Model-predicted log reading times for the switching by trial order interaction. Error bars depict ±1 *SEM*. Note: this interaction was marginal in gaze duration, and it was significant in total reading time.

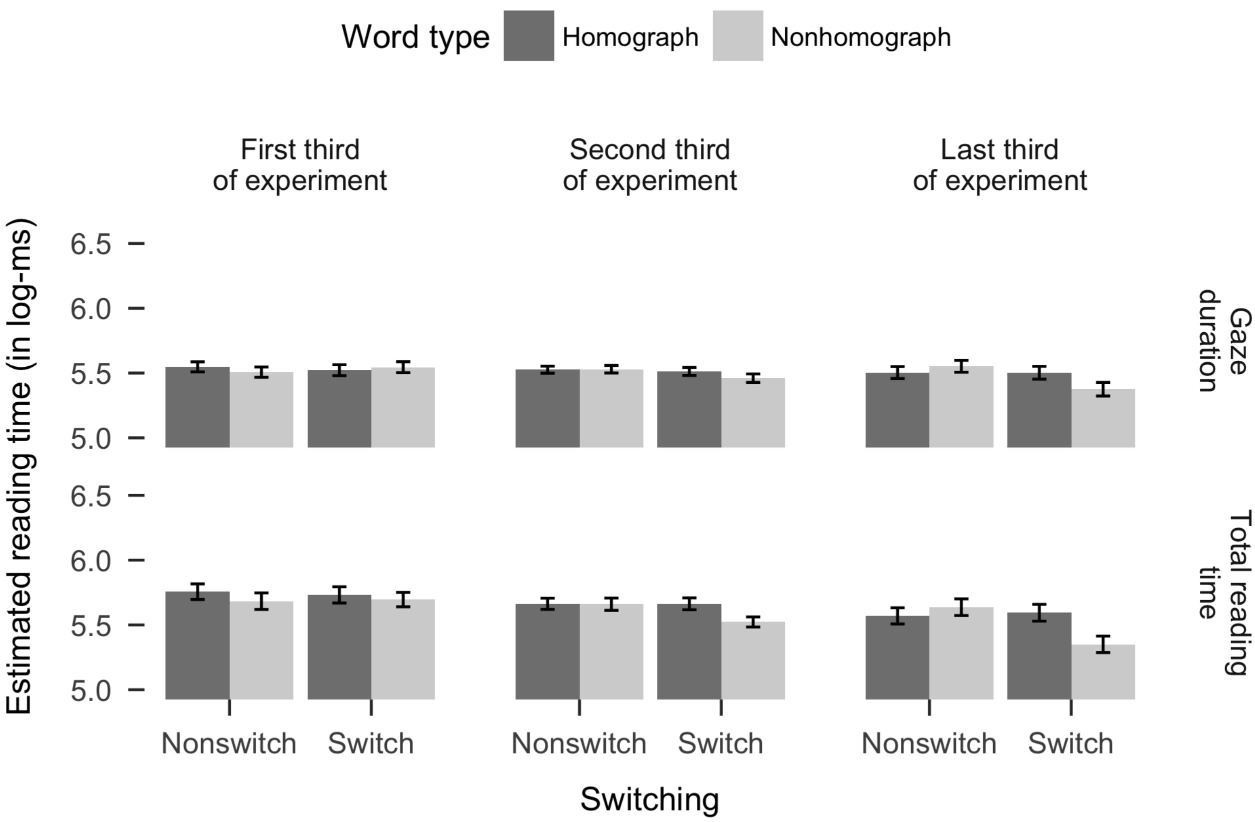

Figure 5. English - French bilinguals reading in L1 (Experiment 2) at the downstream target region. Model-predicted log reading times for the switching by homograph by trial order interaction. Error bars depict ±1 *SEM*. Note: This interaction was not significant in gaze duration, but it became significant in models that included interactions with L2 exposure. This interaction was significant in total reading time.

Table 1

Participant characteristics.

	Experiment 1: L1 French bilinguals: N = 35 N_{Female} = 23		Experiment 2: L1 English bilinguals N = 42 N_{Female} = 33		
Measure	Mean	Standard Deviation	Mean	Standard Deviation	Sig.
Demographics					
Chronological age	22.97	4.20	22.14	4.50	
Age began acquiring L2	8.94	3.04	5.88	3.96	*
Age began reading in L2	12.40	4.00	8.12	4.82	*
English self-ratings (/7)					
Speaking	5.14	1.24	6.98	0.15	*
Reading	5.57	1.04	7.00	0.00	*
Writing	5.00	1.21	6.95	0.22	*
Translating	4.66	1.37	6.57	0.94	*
Listening	5.10	0.89	6.98	0.15	*
Pronunciation	4.71	1.19	6.90	0.30	*
Fluency	5.09	1.29	6.93	0.35	*
Vocabulary	4.69	1.11	6.86	0.52	*
Grammar	5.06	1.35	6.81	0.55	*
Overall competence	5.09	1.12	6.95	0.31	*

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French self-ratings (/7)					
Speaking	7.00	0.00	5.00	1.34	*
Reading	7.00	0.00	5.29	1.24	*
Writing	6.80	0.53	4.41	1.50	*
Translating	6.49	0.89	4.45	1.33	*
Listening	7.00	0.00	5.50	1.24	*
Pronunciation	6.97	0.17	5.03	1.49	*
Fluency	6.94	0.34	5.24	1.13	*
Vocabulary	6.80	0.47	4.31	1.26	*
Grammar	6.66	0.64	4.57	1.60	*
Overall competence	6.94	0.34	4.74	1.23	*
Language exposure (%)					
English	38.54	23.89	74.19	15.82	*
French	59.00	24.25	23.21	15.37	*

Note: * $p < 0.05$ (two sample t-test)

Table 2

Examples of stimuli

Switching	Target type	Sentence
Non-switch	Homograph	After searching for many *hours*, she found a single ***cent*** underneath the bed.
	Homograph-control	While she was cleaning her *house*, she found a single ***book*** underneath the bed.
Switch	Homograph	After searching for many *heures*, she found a single ***cent*** underneath the bed.
	Homograph-control	While she was cleaning her *maison*, she found a single ***book*** underneath the bed.
Non-switch	Cognate	Having been created by a *perfectionist*, the detailed ***photo*** had turned out well.
	Cognate-control	Having undergone multiple *revisions*, the detailed ***essay*** had turned out well.
Switch	Cognate	Having been created by a *perfectionniste*, the detailed ***photo*** had turned out well.
	Cognate-control	Having undergone multiple *révisions*, the detailed ***essay*** had turned out well.

Note: The initial switch region is italicized, and the downstream target region is bolded and italicized. French words in the switch regions are translation equivalents within Target type condition (e.g., *heures* is the translation equivalent of *hours*).

Table 3

Condition means (in milliseconds) for the language switch region. Standard deviations are listed in parentheses.

Group	Measure	Nonswitch	Switch	Switch-Noswitch
Experiment 1: L1	GD	303 (50)	395 (91)	92
French bilinguals				
(N = 35)	TRT	411 (132)	545 (149)	134
Experiment 2: L1	GD	239 (36)	337 (78)	98
English bilinguals				
(N = 42)	TRT	298 (77)	485 (173)	187

Note: GD = gaze duration, reflects early lexical activation; TRT = total reading time, reflects later integrative aspects of lexical processing. SDs are listed in parentheses

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Table 4

Condition means (in milliseconds) for the downstream target region. Standard deviations are listed in parentheses.

			Cognates			Homographs		
Group	Measure	Word type	Nonswitch	Switch	Switch-Nonswitch	Nonswitch	Switch	Switch-Nonswitch
L1 French bilinguals: Experiment 1 (N = 35)	GD	Target	299 (56)	302 (62)	3	314 (76)	316 (67)	2
		Control	318 (63)	322 (86)	4	316 (69)	312 (76)	-4
		Target - Control	-19	-20		-2	4	
	TRT	Target	353 (91)	350 (111)	-3	488 (241)	450 (168)	-38
		Control	383 (110)	399 (160)	16	409 (155)	398 (129)	-11
		Target - Control	-30	-49		79	52	
L1 English bilinguals: Experiment 2 (N = 42)	GD	Target	266 (45)	271 (50)	5	267 (40)	266 (50)	-1
		Control	268 (59)	263 (48)	-5	269 (48)	255 (48)	-14
		Target - Control	-2	8		-2	11	
	TRT	Target	306 (75)	312 (83)	6	331 (92)	345 (105)	14
		Control	306 (76)	303 (90)	-3	324 (85)	292 (58)	-32
		Target - Control	0	9		7	53	

Note: GD = gaze duration, reflects early lexical activation; TRT = total reading time, reflects later integrative aspects of lexical processing. SDs are listed in parentheses