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The impact of a discourse context on bilingual cross-language lexical activation

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Research Article

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Abstract

Four hypotheses regarding the impact of discourse context on cross-language lexical activation were tested. Highly-proficient, Spanish–English bilinguals read all-English paragraphs containing non-identical and identical cognates or noncognate controls while their eye-movements were tracked. There were four paragraph conditions based on a full crossing of semantic bias from the topic sentence and sentence containing the critical word. In analyses in which cognate status was treated categorically there was an interaction between global bias and cognates status such that the observed inhibitory effects of cognate status were attenuated in global-neutral contexts. Follow-up analyses on the non-identical cognates in which orthographic overlap was treated continuously revealed a U-shaped function between orthographic overlap and processing time, which was more pronounced in global-neutral contexts. The overall pattern of findings is consistent with a combined operation of resonant-based and feature-restriction mechanisms of context effects.

1. Introduction

A key characteristic of bilingual reading is that word identification involves activation of lexical representations from both languages. There are now numerous studies demonstrating that when bilinguals encounter words in one language, activation flows across both languages (see Schwartz & van Hell, 2012 and van Assche, Brysbaert & Duyck, 2020 for reviews). Most of the studies supporting language non-selective activation have been based on the processing of single words presented in isolation. Only fairly recently have investigators tested whether effects of cross-language activation are at all modulated when words are presented in a meaningful context, such as a sentence (e.g., Dijkstra, van Hell & Brenders, 2015; Duyck, van Assche, Drieghe & Hartsuiker, 2007; Lagrou, Hartsuiker & Duyck, 2015; Lauro & Schwartz, 2019; Libben & Titone, 2009; Pivneva, Mercier & Titone, 2014; Schwartz & Kroll, 2006; Titone, Libben, Mercier, Whitford & Pivneva, 2011; van Assche, Drieghe, Duyck, Welvaert & Hartsuiker, 2011; van Assche, Duyck & Brysbaert, 2013; van Assche, Duyck, Hartsuiker & Diependaele, 2009; van Hell & de Groot, 2008). A consistent finding across these studies is that the presence of a sentence context, in and of itself, is not sufficient to eliminate cross-language lexical activation (see Schwartz & van Hell, 2012 and van Assche, Duyck & Hartsuiker, 2012 for reviews). However, the picture is still mixed regarding whether a strongly semantically-constraining context directly constrains the flow of activation across languages. To date, studies that have directly compared the effects of low- versus high semantically-biasing contexts have focused solely on the effects of a local sentence context (Lauro & Schwartz, 2019; Libben & Titone, 2009; Pivneva et al., 2014; Titone et al., 2011; van Assche et al., 2011).

In the present study we tested whether semantic bias provided at both the local (sentence) and global (discourse topic) levels modulates effects of cross-language activation on lexical access. Before describing the present study in more detail we first review, (1) the relevant literature on cross-language lexical activation, (2) how cross language activation effects are modulated by sentence context and finally, (3) theoretical accounts of how context affects lexical access.

Cross-language activation of lexical representations across languages

One of the most robust effects demonstrating that activation flows in a language non-selective manner within the bilingual lexicon has been cognate facilitation. Cognates are words across languages that have the same meaning and are either identical in lexical form or are highly similar (e.g., *emotion/emoción* in English and Spanish). Cognate facilitation effects have been observed in a variety of tasks such as lexical decision (e.g., Bultena, Dijkstra & van Hell, 2013; Lemhöfer & Dijkstra, 2004), progressive demasking (e.g., Lemhöfer et al., 2008) semantic categorization (Sánchez-Casas, Davis & García-Albea, 1992), picture naming (Hoshino & Kroll, 2008), and translation (de Groot, Dannenburg & van Hell, 1994).

Cognate facilitation effects have also been observed across numerous language pairs, including those that do not share a script (Gollan, Forster & Frost, 1997; Hoshino & Kroll, 2008; Nakayama, Sears, Hino & Lupker, 2012). Cognate status has been shown to facilitate processing whether it be in the non-dominant language (L2) or dominant language (L1) (van Assche et al., 2009), and these effects have even been observed when the cognate status is shared with a relatively weak L3 (Lemhöfer, Dijkstra & Michel, 2004; van Hell & Dijkstra, 2002). Furthermore, for trilinguals, the magnitude of the facilitation effect is larger for triple cognates (whose status applies to all three language) relative to "double" cognates (Lemhöfer et al., 2004).

Although facilitative effects of cognate status are fairly robust, the magnitude of the facilitation has been shown to be modulated by the degree of overlap in lexical form. Several studies have found that facilitation effects decrease as a function of decreasing overlap in orthographic form (e.g., Duyck et al., 2007; Schwartz, Kroll & Diaz, 2007). In fact, certain task demands and contexts can cause the distinct lexical form representations to compete, incurring a cost in processing (e.g., Guasch, Ferré & Haro, 2017; Schwartz et al., 2007). The graded effects of cognate facilitation, which can turn inhibitory in some cases, has led to the proposal that non-identical cognates are represented differently in the lexicon than identical cognates. According to one account, the bilingual interactive activation plus model (BIA+) (Dijkstra & van Heuven, 2002), non-identical cognates are represented twice in the lexicon, whereas identical cognates have a single representation (see Dijkstra, Miwa, Brummelhuis, Sappelli & Baayen, 2010 for further specification of this distinction). More specifically, non-identical cognates (e.g., *benefit/beneficio* across English and Spanish) have distinct representations at the orthographic, phonological and morphemic levels, and these map on to a shared semantic representation. Cognate facilitation is the result of convergent bottom-up and top-down activation between co-activated orthographic and phonological units and shared semantic units. The degree of the facilitation is a function of the degree of overlap between the lexical form units. The model includes lateral inhibition between competing units. Therefore, co-activated units of cognates that are more distinct in lexical form can compete and produce cognate inhibition. Whether the nature of the cognate effect is a cost versus a benefit depends on the extent to which the task requires specification of the language specific readings of the cognate in order to make a response.

Cross-language lexical activation in context

At the time of the publication of the BIA+ (Dijkstra & van Heuven, 2002), there were few published studies that directly tested the effect of context on language non-selectivity. The modelers proposed that sources of information from a linguistic context can directly affect activation dynamics within the lexicon. They posited that syntactic or semantic information provided by a preceding sentence context "may exert serious constraints" (p. 187) on the degree to which activation flows non-selectively (Dijkstra & van Heuven, 2002). Shortly after its publication, there were several studies that examined whether the presence of a sentence context modulates cross-language activation. A common approach has been to compare effects of cognate or interlingual homograph status when these are preceded by a low-constraint (*Many people read about the* ***bomb***…) versus high-constraint (*The terrorists had planted a* ***bomb***..) sentence context. One conclusion that can be drawn from this literature is that the mere presence of a sentence context is not sufficient to override cross-language activation. Virtually all of the studies converge in finding persistent effects of language non-selectivity such as cognate facilitation in low semantically-constrained sentences (e.g., *Many people read about the*…) (Bultena, Dijkstra & van Hell, 2014; Dijkstra et al., 2015; Duyck et al., 2007; Gullifer, Kroll & Dussias, 2013; Lagrou et al., 2015; Libben & Titone, 2009; Pivneva et al., 2014; Schwartz & Kroll, 2006; Titone et al., 2011; van Assche et al., 2009, 2012; van Hell & de Groot, 2008) and interlingual homograph inhibition (Libben & Titone, 2009; Pivneva et al., 2014; Schwartz & Kroll, 2006; Titone et al., 2011). This implies that the language membership information a sentence context provides is not sufficient to restrain activation to just one language.

What about semantically rich contexts that afford a combination of semantic, syntactic and language membership feature restrictions? Are these sufficient to constrain the flow of activation to just one language? Although findings have been somewhat mixed, with some studies showing no attenuation of cognate facilitation effects in high-constraint relative to low-constraint sentences (e.g., van Assche et al., 2011), and others finding a complete elimination of these effects (e.g., Schwartz & Kroll, 2006; van Hell & de Groot, 2008), these discrepancies can be largely resolved by considering differences in task demands and the relative sensitivity of the measures used across different experiments. In two of the earliest studies that examined the influence of sentence context on cross-language activation, cognate facilitation effects were observed in low constraint sentences but eliminated in high constraint contexts (Schwartz & Kroll, 2006; van Hell & de Groot, 2008). Both of these studies used tasks in which participants made an overt response to the target words such as naming, making a lexical decision or translating. It has been argued elsewhere (van Assche et al., 2012) that these task requirements are not part of natural reading and might artificially disrupt cross-language activation. In two other studies in which participants made overt responses to target words, cognate facilitation effects were observed in both low- and high-constraint sentences (Dijkstra et al., 2015; Gullifer et al., 2013). Both of those studies included a high degree of language intermixing (e.g., inter-sentential and intra-sentential switching), which may have extended the timeline of cross-language activation flow.

A critical limitation of studies based on overt responses is they lack sufficient temporal resolution to capture lexical activation dynamics that unfold across time. There now have been several studies that have used eye-tracking to examine the effects of sentence context on language non-selectivity (e.g., Duyck et al., 2007; Libben & Titone, 2009; Pivneva et al., 2014; Titone et al., 2011; van Assche et al., 2009, 2012). These studies have provided a more precise understanding of how the magnitude and time-course of cross-language activation is modulated by semantic information from context, stimulus characteristics and language proficiency. One key finding from eye-tracking studies is that the extent to which effects of cross-language activation are observed depends critically on the cross-language lexical form overlap of the cognate word stimuli (Duyck et al., 2007; van Assche et al., 2009, 2012). For example, in one study (Duyck et al., 2007) Dutch–English bilinguals read all L2, low-constraint sentences. Significant cognate facilitation effects were only observed for the identical cognates, no effects were observed for those that were not identical. This is particularly striking since the words were embedded in low-semantically constraining

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contexts. In later studies, in which orthographic overlap between cognate translations was treated continuously, significant facilitation effects, modulated by overlap, were observed across low and high constraint sentences, in both L2 and L1 sentence processing (van Assche et al., 2009, 2012). Observing consistent effects of cognate status in low- and high-constraint sentences (and in the L1 as well as the L2) has led the authors of these studies to conclude that sentence context does not directly constrain the non-selective nature of bilingual lexical activation (van Assche et al., 2012).

However, results from other eye-tracking studies provide some evidence that the added semantic information from a context can in fact limit the extent to which activation flows across languages. In one study, Libben and Titone (2009) examined how sentence constraint might modulate effects of cognate status and interlingual homograph status with highly-proficient French–English bilinguals reading all L2-sentences. Significant cognate facilitation and interlingual homograph inhibition were observed in low-constraint sentences across measures tapping into early stages of lexical access (e.g., gaze duration) as well as later stages (e.g., total reading time). In high-constraint sentences, however, these effects were only observed in early measures of processing. This suggests that a strong, semantic bias may limit the time-course in which activation continues to flow in a language non-selective fashion.

In a follow-up study (Pivneva et al., 2014) the same stimulus list as Libben and Titone (2009) was presented to another group of French–English bilinguals. However, these bilinguals were less proficient in English than those in the Libben and Titone (2009) study. Unlike the earlier study, cognate facilitation effects were observed across high- and low- constraint sentences. These effects were qualified by an interaction with age of acquisition, such that later L2 acquirers showed larger cognate effects across contexts. A similar relationship between the magnitude of cognate effects and proficiency in the non-target language was observed in another study with participants reading in their L1 (Titone et al., 2011). In that study, cognate facilitation effects were attenuated in high-constraint sentences and the relative magnitude of cognate facilitation was greater as a function of increasing proficiency in the L2.

A recent meta-analytic study (Lauro & Schwartz, 2017) provides further evidence that semantic constraints from a sentence context can limit the degree to which lexical activation flows non-selectively across languages. They compared the pooled cognate status effect size across twenty-six different studies in which cognates were presented in either low- or high-constraint sentences. The effect size from experiments based on high semantic- constraint sentences was significantly smaller (though still significant) from the pooled effect size from experiments based on low semantic-constraint sentences.

The studies on context reviewed above were based on single sentence processing. To the best of our knowledge there have been two published studies that have examined effects of cross-language activation for words embedded in a larger discourse (Balling, 2013; Cop, Dirix, van Assche, Drieghe & Duyck, 2017). In the study by Cop and others, Dutch–English bilinguals read an entire novel, either in their L1 or L2 while their eye-movements were tracked. The authors analyzed processing time of cognates embedded in the novel that ranged in their orthographic overlap and included identical cognates. Cognate facilitation effects were observed in both L1 and L2 conditions and across a range of eye-movement measures tapping into early (first fixation duration) and late stages of processing (go-past measures). This suggests that the effect of cognate status can affect even relatively late stages of comprehension, such as textual integration. For non-identical cognates they observed a linear relationship between orthographic overlap and processing time.

In another study in which cognate effects were examined in a discourse context (Balling, 2013), Danish–English bilinguals read newspaper articles in their L2 while their eye-movements were monitored. As in the Cop et al. study, they observed cognate facilitation effects in measures reflecting earlier stages of processing (gaze duration) and later stages (total reading time). Importantly, the effects of cognate status depended on the contextual appropriateness of the cognate meaning. For example, the Danish–English cognate *addresse/address* refers to a place of residence in both languages but only in English can it be used as a verb and refer to a speech act. When the stimulus cognates were in contexts in which the L2 –unique meaning was used, cognate facilitation effects were not observed.

Theoretical mechanisms of context effects on lexical access

What is the mechanism through which semantic information from context constrains non-selectivity? Based on the literature we discerned four different hypotheses regarding the effect of a discourse context on cross-language activation. The first two hypotheses are compatible with the architectural assumptions of the BIA+ (Dijkstra & van Heuven, 2002) but they propose different mechanisms. First, is the resonant activation hypothesis. The architecture of the BIA+ includes resonant activation between semantic and orthographic units which can accelerate lexical access. Semantic bias from local and global contexts can combine, further accelerating access. This could allow access to outpace the spread of activation across languages eliminating its observable effects. If context effects are based primarily on resonance then cognate effects should be either eliminated or reduced in the global-biasing/local-biasing condition relative to the other three conditions.

Second, is the "feature generation" hypothesis. According to the feature restriction account (Schwanenflugel & LaCount, 1988; Schwanenflugel & Shoben, 1985), readers generate feature restrictions for upcoming words as they read through a sentence. These features can be semantic/pragmatic, lexical or syntactic. Processing of words is facilitated to the extent that a word matches the various feature restrictions that have been generated. A mismatch with the features, on the other hand, delays processing. Take as an example the following semantically-biasing sentence: "*The neighbor's dog would not stop….*" . Here semantic features would restrict activation to words that refer to something that dogs do, with greater activation flowing to words that are highly associated with dogs. Syntactic features would restrict activation to words in the proper present progressive verb tense. The combination of these features restricts activation to a specific, highly expected word, "barking". If that is in fact the word encountered, its processing is facilitated relative to if it had been preceded by a neutral context. In contrast, if the final word was unexpected – for example, the plausible, but unexpected completion "*sneezing*" – processing will be delayed. Therefore, according to this account, highly biasing contexts produce strong facilitation of expected words and inhibition of any other alternatives. In contrast, features generated from less semantically biasing contexts do not constrain activation as severely. For example, features generated from a sentence (such as "*The neighbor's son would not*

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stop") will be consistent with a much larger cohort of word representations and activation will flow more diffusely amongst them. As a consequence their processing will be facilitated (though less strongly than a highly-expected word).

One study extended the assumptions of the feature restriction to discourse processing in which a global context was provided (Schwanenflugel & White, 1991). Participants read paragraphs ending in a sentence whose final word was either expected given the local sentence context (e.g., *The hikers slowly climbed up the* ***mountain***) or unexpected (e.g., *The hikers slowly climbed up the* ***stairs***). To examine whether semantic information provided at a global context level influenced the number and specificity of feature restrictions generated, the authors embedded these sentences in paragraphs in which the topic sentence was either consistent with the locally unexpected completion of the sentence (*stairs*: *After a treacherous hike Bill and his friends sluggishly entered the apartment lobby*) or with the expected completion (*mountain*: *The hiking trip was the most strenuous that the group had taken*). The critical finding was that, when the topic sentence was consistent with the locally-unexpected completion, facilitated processing was observed for both expected and unexpected completions. The interpretation was that there was a more diffuse spread of activation amongst a larger cohort of possible completions due to a broader range of feature restrictions that had been generated from global and local contextual biases.

Since the BIA+ allows for language-related information, such as syntactic and pragmatic information to constrain lexical activation within the bilingual lexicon, its architecture allows for feature restrictions to constrain or modulate effects of language non-selectivity (Dijkstra et al., 2015; Dijkstra & van Heuven, 2002). Consistent with this proposal an earlier study on bilingual sentence comprehension had provided evidence that bilinguals generate language-specific form feature constraints for upcoming words (Altarriba, Kroll, Sholl & Rayner, 1996). In that study Spanish–English bilinguals read sentences in the L2 that either biased the meaning of an upcoming target word or were relatively neutral. On critical trials the target word was a code-switched L1 word (*He wanted to deposit all of his* ***dinero*** *at the credit union*) of either high or low frequency. When the code-switched words were of high frequency and inserted in biasing contexts, interference effects were observed in processing time. This suggests that the semantic bias provided by the sentence caused readers to generate a specific set of both semantic and lexical form feature restrictions. The high frequency L1 word conformed with the semantic features but violated the form features of the language-specific expected word.

Therefore, according to a feature restriction hypothesis, bias at the local level will produce form feature restrictions, pertaining to specific word representations, whereas bias at the global level will produce semantic restrictions, which will be fewer and more general than those generated from a local bias. Consequently the effects of context, particularly for non-identical cognates, should depend on whether there is bias at the local or global level. In local biasing contexts there should be a cost in cognate processing time due to the competing lexical forms. In global-biasing/local-neutral contexts there should be cognate facilitation effects.

Another possibility is that the mere presence of a global context fundamentally alters the nature of comprehension processes in a way that completely eliminates cross-language activation. The "extreme selectivity" hypothesis is based on emerging evidence that effects of cross-language interactivity can be overridden when word processing is highly dependent on its integration with the surrounding context. For example, two separate studies (Bultena et al., 2014; van Assche et al., 2013) have found reduced facilitation effects for cognate verbs relative to nouns in sentence contexts. The argument is that this reduction occurs for verbs because the comprehension of verbs is more contextually dependent than nouns. This logic can be extended to discourse comprehension. Specifically, the on-going, top-down process of integrating the representation of the clause or sentence in which cognates are embedded into the larger, discourse representation may override effects due to bottom-up lexical activation dynamics. The "extreme selectivity" hypothesis leads to the prediction that processing times for cognates and noncognates should be similar across all global and local context conditions.

Finally, we must consider the possibility that the presence of a meaningful context has no effect on the cross-language spread of lexical activation. We refer to this possibility as the "extreme non-selective" hypothesis. This hypothesis is based on bilingual sentence context studies that have shown no effects of sentence context on cognate facilitation (e.g., Duyck et al., 2007; van Assche et al., 2009, 2012). The extreme non-selective hypothesis predicts that the magnitude and nature of cognate effects will be the same across the four different global and local biasing conditions.

As reviewed earlier, there have been two published studies that have examined cognate effects in discourse context (Balling, 2013; Cop et al., 2017). Both studies converge in finding evidence that bilingual lexical activation remains language non-selective in nature, even in discourse processing. However, although it is a positive feature that both studies used authentic texts, it means that the degree of contextual bias and cognate form overlap were not systematically controlled. Also, neither study disentangled the effects of local versus global sources of bias. Therefore, it is not possible to conclude whether either study supports one of the four aforementioned hypotheses more than the other, though they clearly are inconsistent with an "extreme selectivity" hypothesis.

The present study

In the present study we tested the four hypotheses of context effects on cognate processing by creating paragraph stimuli based on a completely crossed design of global and local bias. Global bias was instantiated through the topic sentence of the paragraph. Local bias was instantiated in the second sentence, which contained the target word, either a cognate or noncognate control. Highly-proficient Spanish–English bilinguals read the paragraphs while their eye-movements were tracked. We report two sets of analyses. In one set cognates status is treated categorically to examine overall effects of cognate status on reading times. The second set of analyses focused specifically on non-identical cognates. For this set we tested whether effects of bias from context on cognate processing would be modulated by the degree of lexical form overlap.

Methods

Participants

Potential participants completed informed consent procedures and were treated in accordance with APA ethical guidelines for

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Table 1. Participant proficiency characteristics (standard deviations in parentheses)

	English		Spanish	
Age of Acquisition	4.1 (*4.4*)		1.3 (*2.2*)	
	Self-rated proficiency[2,3]			
Speaking	8.4 (*1.4*)		6.9 (*2.5*)	
Reading	8.5 (*1.7*)		6.1 (*2.8*)	
Comprehension	8.9 (*1.3*)		7.5 (*2.4*)	
	Age Equivalency	Standardized Score	Age Equivalency	Standardized Score
Picture Vocabulary[1]	13.2 (*6.5*)	35.8 (*7.8*)	8.2 (*4.3*)	34.9 (*11.0*)
Passage Comprehension[1]	14.3 (*7.2*)	24.0 (*4.4*)	11.3 (*6.6*)	21.4 (*5.3*)

[1]Derived from WMLS-R
[2]Derived from LEAP-Q
[3]On a scale of 1- 10

human subjects research. An original sample of 40 university students participated in the study. Data from 2 participants were corrupted and excluded from the analyses. Proficiency across English and Spanish was assessed through the picture vocabulary and passage comprehension subtests of the Woodcock-Muñoz Language Survey (WMLS-R) (Woodcock, Muñoz-Sandoval, Ruef & Alvarado, 2005) and through responses on the Language Experience and Proficiency Questionnaire (LEAP-Q) (Marian, Blumenfeld & Kaushanskaya, 2007). Five of the participants self-reported being monolingual speakers of English and rated their Spanish abilities at zero on the LEAP-Q and their data were not included in the analyses, leaving an analyzable sample of 33. The means and standard deviations on the age equivalency scores on the WMLS-R subtests and the self-assessed proficiency ratings are summarized in Table 1.

On average, participants reported acquiring Spanish at a younger age (M = 1.3 years) than English (M = 4.1 years). Proficiency ratings in English were significantly higher than in Spanish, $t(32) = 2.88$, $p < .05$, indicating that most participants were L2-dominant. This reflects the fact that considerably many participants were native speakers of Spanish, who had received most of their formal schooling in English. Although this may typically be considered an example of heritage language speaking, it should be noted that participants were living along a bi-national, bilingual and bi-cultural border region in which both of their languages were used throughout the day and through formal and informal contexts. In fact, on average participants estimated that they were exposed to English 57% of the day and Spanish for the remaining 43%. Responses on the LEAP-Q indicated that both English and Spanish were used on a regular basis in places of work and education. As summarized in Table 1, means scores on the WMLS-R subtests and self-assessed proficiency ratings were consistently higher in English than in Spanish, suggesting an L2- dominance. Paired sample t-tests on the WMLS-R standardized scores revealed a significant difference between the scores on the passage comprehension test, $t(32) = 2.23$, $p < .05$, reflecting higher scores in English than Spanish; scores on the picture vocabulary test were not significantly different, $t(32) = 1.15$, $p = .26$.

Design

The present study was based on a 2 (global context) X 2 (local context) X 2 (cognate status) within-participants design. There were five dependent variables: skipping rates, first fixation duration (FFD), gaze duration (GD), spillover duration, and total reading times (TRT). FFD is the duration of the first fixation made on the critical word, GD is the sum of the duration of all fixations made on the word before moving forward (rightward) in the text. Both of these measures are generally assumed to reflect processes that unfold prior to the completion of lexical access. TRT is the sum of all fixations made on the critical word, including regressions that are made after having moved forward in the text. This measure is assumed to capture post-lexical access integration processes. Spillover is assumed to reflect a measure of the window of processing occurring shortly before and after lexical access of the critical word. A word may be skipped if there is sufficient information from the parafoveal region to identify a word and can also be considered a measure that reflects processing before the completion of lexical access (see Rayner, Chace, Slattery & Ashby, 2006; Rayner, 2009). The results of the analyses are organized in sequence of the processing time window they are assumed to reflect (i.e., skipping rates, FFD, GD, spillover, TRT).

Stimuli

Critical words

Thirty-eight Spanish–English cognate nouns were matched in frequency of occurrence per one million words and length on an item-by-item basis with noncognate nouns using the Clearpond online database (Marian, Bartolotti, Chabal & Shook, 2012) (see Table 2, for examples of stimuli and lexical characteristics; and Appendix A for a full listing of materials, Supplementary Materials). Eight of the cognates were orthographically identical across languages; the other forty were non-identical. To obtain an objective measure of the degree of orthographic form overlap of the cognates we calculated the orthographic similarity ratio developed by van Orden (1987). This measure includes a consideration of the number of single shared letters, the number of pairs

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Table 2. Lexical characteristics of critical words, production probabilities from norming and example paragraph stimuli for cognates (second column) and noncognates (third column) for each of the four, paragraph conditions

	Cognates	Noncognates
Frequency[1]	50.60	51.79
Length	5.74	5.79
Graphemic Overlap Ratio[2]	0.75 (0.16)	
Production Prob[3]. Local Neutral	1.6%	1.5%
Local Biasing	72.0%	81.1%
	Example Paragraph Stimuli	
Global Neutral/ Local Neutral	Rodrigo always dreamed of achieving his goal. He had worked for many years and his skill as an **actor** was growing. His mentor warned him that it was a tough career goal to pursue.	Rodrigo worked to achieve his goals. He was constantly praised for his skill as a **cook**, and won several local contests. Although very demanding, it was the perfect career for him.
Global Neutral/ Local Biased	Rodrigo always dreamed of achieving his goal. He had performed in many plays and wanted to be an **actor** known worldwide. His mentor warned him that it was a tough career goal to pursue.	Rodrigo worked to achieve his goals. He had prepared many meals and his skill as a **cook** was widely known. Although very demanding, it was the perfect career for him.
Global Biased/ Local Neutral	Rodrigo always dreamed of being on stage. He had worked for many years and his skill as an **actor** was growing. His mentor warned him that it was a tough career goal to pursue.	Rodrigo dreamed of owning a restaurant. He was constantly praised for his skill as a **cook**, and won several local contests. Although very demanding, it was the perfect career for him.
Global Biased/ Local Biased	Rodrigo always dreamed of being on stage. He had performed in many plays and wanted to be an **actor** known worldwide. His mentor warned him that it was a tough career goal to pursue.	Rodrigo dreamed of owning a restaurant. He had prepared many meals and his skill as a **cook** was widely known. Although very demanding, it was the perfect career for him.

[1]Occurrence per 1 million words. The CELEX lexical database (Kerkman et al., 1995).
[2]Based on formula and ratio described in Van Orden (1987)
[3]Production probability of critical word from norming procedures

of letters shared in forward and reverse order, and whether the first or last letters of the word pair are shared or not. All but one cognate (*student/estudiante*) had a graphemic overlap ratio of 0.5 or greater.

Critical sentences

Two sentences were created for each cognate and noncognate, one in which the initial portion of the sentence semantically biased the target cognate or noncognate and one that did not provide a semantic bias. Critical words were always in the middle of the sentence and, to the extent possible, preceded by short function words such as "the", "a", or "of". To verify the semantic constraint manipulation we presented the initial portions of the sentences, up to, but not including, the critical word, to 31 Spanish–English bilinguals from the same population as the critical experiment and asked them to write a completion of the sentence. For each sentence we calculated the percent of respondents who provided the target word as their completion. The biasing sentence contexts had an average production probability of 76% and the neutral sentence contexts had an average of 1.5%. Fifteen of the biasing sentence contexts were rewritten because less than half of the sample provided the intended target word as the first word of their completion and 12 of the low constraint sentences were re-written because the target or a particular word was given 10% of the time or more.

Stimulus paragraphs

Paragraphs consisted of 3 sentences: a topic sentence, the critical sentence containing the critical word, and a concluding sentence (see Table 2). For each critical cognate and noncognate word, two topic sentences were created; one unrelated to the critical word (e.g., actor: "Rodrigo always dreamed of achieving his goal") or one containing a word that was semantically related to the critical word (e.g., actor: "Rodrigo always dreamed of being on stage"). Four paragraph versions were created by fully crossing the two topic sentence types (neutral, biasing) with the two critical sentence types (neutral, biasing). All four paragraphs ended with the same, third, concluding sentence. For half of the trials, paragraphs were followed by a comprehension question with a two forced-choice answer. Since the questions were formulated to address the subject of the paragraph, the correct response to the question was most often the same word that served as the target interest area in the critical sentence. In this way we were able to check for overall comprehension of the paragraphs as well as attention to the target word.

Apparatus

An SR Re-search Eye-Link 1000 tower mounted system was utilized to record participant eye movement data. Eye movements were recorded from the right eye. Participants were presented with sentences written in black 24pt Times New Roman font on a white background. Paragraphs were displayed at the center of the screen which was positioned 60 cm from a chin rest in which the participant's head rested.

Procedure

After providing informed consent, participants were accompanied to a private testing room. After performing a nine-point calibration for eye tracking, participants were instructed to read a series of paragraphs presented on the computer screen at their own

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pace. They were informed that on most trials the paragraphs would be followed by comprehension questions. Participants were presented with ten practice trials in order to familiarize them with the task. Each paragraph was preceded by a fixation point, located where the first word of the paragraph would appear, that participants were asked to look at directly before pressing the spacebar key in order for the paragraph to appear. Once the participant was done reading at their own pace, they were asked to press the spacebar again to continue to the next paragraph. A drift check was performed after each trial. On half of the trials, paragraphs were followed by a two-choice comprehension question. Each participant was presented with a total of 76 paragraphs and 38 follow up questions. After the reading task, participants were asked to complete the LEAP-Q and WMLS-R questionnaires. In total the experiment took about 90 minutes to complete.

Data treatment

Data trimming

All fixations throughout all regions of the stimulus paragraphs that were shorter than 100 ms were removed from the data files and not included in analyses: this resulted in removal of 5% of all fixations made throughout the stimulus paragraphs and across all participants. Also, any fixations longer than 2000 ms were removed, resulting in the removal of an additional .05% of all fixations. Finally, any first fixation durations, gaze durations and total reading times that were longer or shorter than 2.5 standard deviations of the participant's overall mean were removed, resulting in removal of 0.7% of the data.

Data exclusions

Data from trials in which participants answered the follow-up comprehension questions incorrectly were removed (n = 33), which was 0.67 of all trials.

Results

Overall effects of cognate status

Analytic approach

Analyses were performed on fixations within the critical region, which consisted of the target word, and in the case of spillover, the word immediately following the target word. To test for the overall effect of cognate status across the four different contextual bias conditions, we first performed analyses in which we treated cognate status categorically. The reader should note, as described in the stimulus section, that most of the cognates were non-identical (n = 30): however, there were also eight identical cognates. All data were log-transformed for analyses[1]. We constructed Linear Mixed Effects (LME) models using the *buildmer* library (Voeten, 2020) within R (R Core Team, 2017). This function uses lmer from the lme4 package and starts by attempting to fit the most maximal model. If the fully maximal model does not converge the function simplifies the random effects structure using stepwise elimination. The function calculates p-values for all fixed effects based on Satterthwaite denominator degrees of freedom using the lmerTest package (v. 3.1-2; Kuznetsova, Brockhoff & Christensen, 2017). The original, full maximal models contained four fixed factors: global context (neutral, biasing), local context (neutral, biasing), cognate status (noncognate, cognate) and their interaction. All fixed factors were coded and centered around 0. The random effects structure included random slopes and intercepts for all fixed factors and their interaction by subjects only (all factors were binary item characteristics). All models and their associated statistics are listed in Appendix B (Supplementary Materials).

Skipping rates

Because skipping data is binomial, skipping rates were analyzed using logistic mixed effects regression models. The final model included random intercepts and slope adjustments for all three factors (skipping rate ~ cognate status * local bias * global bias + (1 | word) + (1 + cognate status + local + global | subject). Skipping rates were significantly higher for words embedded in global biasing contexts (M = 7.9%) relative to global neutral contexts (M = 4.5%), $b = -0.71$, $SE = 0.23$, $z = -3.17$, $p < .05$. There were no other significant main effects of interactions (all p's > .05).

First fixation duration

The final model was: *ffd ~ cognate status * local bias * global bias + (1 | word) + (1 | subject)*. Durations were significantly shorter for words embedded in local-biasing contexts (M = 207) relative to local-neutral contexts (M = 209), $b = -1.17$, $SE = 5.59$, $t = -2.10$, $p < .05$. There were no other significant main effects of interactions (all p's > .05).

Gaze duration

The final model was: *gd ~ cognate status * local bias * global bias + (1 | word) + (1 | subject)*. Durations were significantly shorter for words embedded in local-biasing contexts (M = 230) relative to local-neutral contexts (M = 246), $b = -2.29$, $SE = 6/44$, $t = -3.55$, $p < .05$. There was a significant interaction between cognate status and global context, $b = -3.09$, $SE = 1.30$, $t = -2.39$, $p < .05$. This interaction reflected the fact that, in global neutral contexts, gaze durations for cognates were *slower* than for noncognates (see Figure 1), $t(32), = 1.96$, $p = .05$, whereas in biasing contexts the durations did not differ significantly, $t(32), = 1.45$, $p = .15$.

Spillover

The final model was: *spillover ~ cognate status * local bias * global bias + (1 | word) + (1 | subject)*. There were no significant main effects or interactions (all p's > .05)

Total reading time

The final model was: *(trt ~ cognate status * local bias * global bias + (1 | word) + (1 | subject)*. Total reading times were shorter for words embedded in local-biasing contexts (M = 303), relative to local-neutral contexts (M = 329) (see Figure 3), $b = -3.17$, $SE = 8.55$, $t = -3.71$, $p < .05$. There were no other significant main effects of interactions (all p's > .05).

In summary, the categorical analyses revealed effects of context and cognate status. First, processing times were shorter for words in local biasing contexts than in non-biasing contexts, which was observed in first fixation, gaze duration and total reading time. This demonstrates that the bias manipulated was in fact effective. Second, we observed an inhibitory effect of cognate status in gaze duration, particularly when these were embedded in global-neutral contexts. In fact, review of Figure 1 shows that this

[1]There are various approaches to treating skewed distributions. We opted for the more conservative approach of log transforming all data. However, it should be noted that this approach may be too conservative particularly in detecting significant interactions (Lo and Andrews, 2015).

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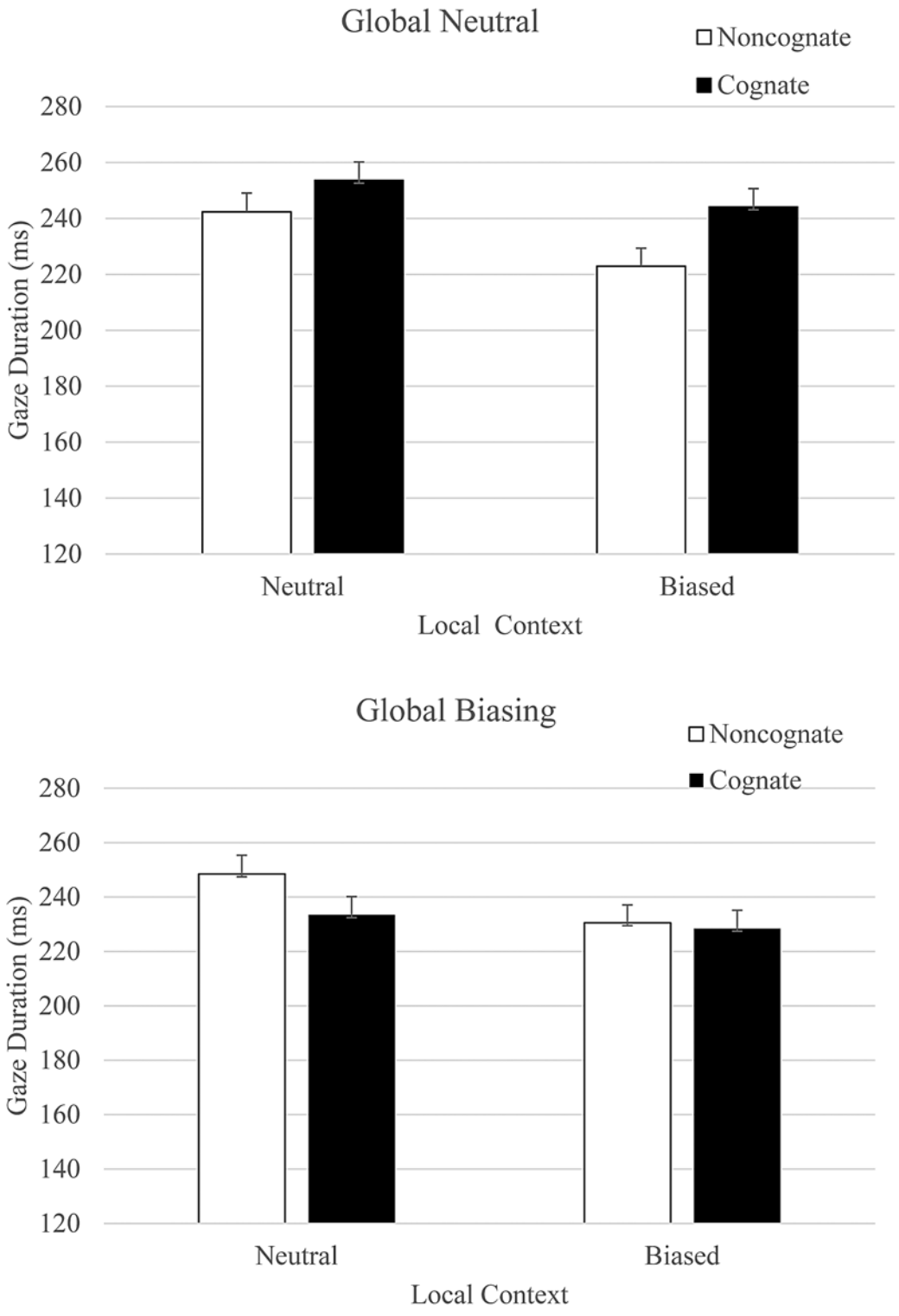

Fig. 1. Means gaze duration for cognates and noncognates across global neutral (top panel) and global biasing (bottom panel) contexts.

inhibitory effect is driven primarily by the inflated processing times in global-neutral/local-biasing contexts. Because most of the cognates were non-identical, this suggests that there was competition between the co-activated, alternative lexical forms of the cognates. Although the three-way interaction with local context was not statistically reliable, the fact that the cost is numerically greatest in local-biasing contexts is consistent with the predictions of a feature-restriction account of context effects. That is, the local biasing context may have produced lexical form specific feature restrictions, which increased competition from the co-activated forms.

There were no effects of cognate status in total reading times. As is evident in Figure 2, the means for cognates and noncognates are virtually identical in global biasing/neutral biasing contexts, suggesting that when there is strong semantic bias provided at

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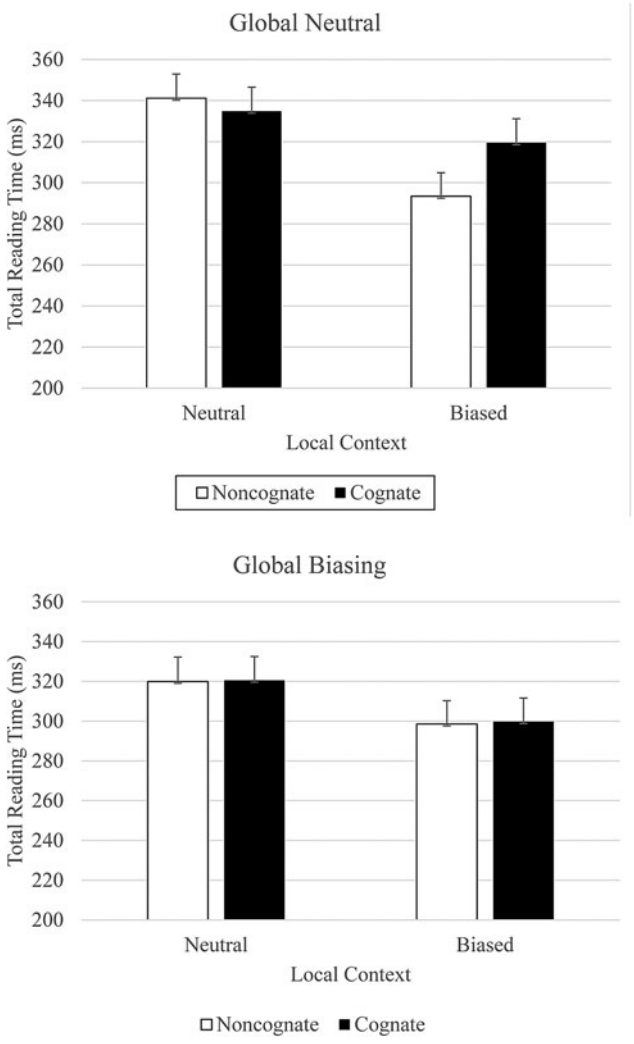

Fig. 2. Means total reading time for cognates and noncognates across global neutral (top panel) and global biasing (bottom panel) contexts.

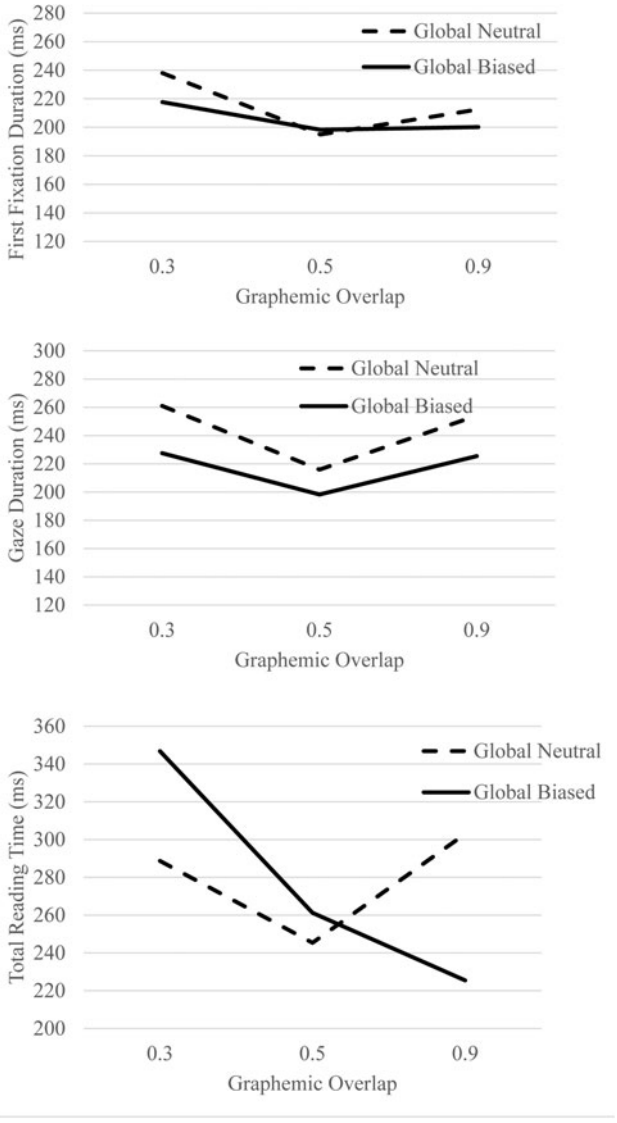

Fig. 3. Mean first fixation durations (top panel) gaze durations (middle panel) and total reading times (bottom panel) as a function of orthographic overlap of non-identical cognates in global neutral and global biasing contexts.

the global and local levels, and processes occurring after initial lexical access are unaffected by co-activated language form. However, treating cognate status categorically might not tell the full story, especially given the evidence of the modulating role of lexical form overlap on cognate processing. We next report analyses on the non-identical cognates only in which we entered graphemic overlap as a continuous factor.

Graded effects of orthographic overlap

Analytic approach

To test for more graded effects of cognate status that can occur as a function of lexical form overlap, we performed a second set of analyses ON NON-IDENTICAL COGNATES ONLY, in which the fixed factor was the van Orden (1987) measure of graphemic overlap. As reviewed previously, identical cognates may be represented in qualitatively different ways than non-identical cognates, with only the latter having two, separate representation (e.g., Dijkstra et al., 2010; Dijkstra & van Heuven, 2002). We treated cognate status continuously and, as with the categorical analyses reported above, data was log-transformed and we constructed Linear Mixed Effects (LME) models using the *buildmer* library (Voeten, 2020) within R (R Core Team, 2017).

Skipping rates

The final model was: *skip* ~ *graph* * *local* * *global* + (*1* | *word*) + (*1* + *graphemic overlap* + *local* + *global* | *subject*). There were no main effects of interactions (all p's > .05).

First fixation duration

The final model was: *ffd* ~ *1* + *local* + *global* + *local:global* + *graphemic overlap* + *local: graphemic overlap* + *global: graphemic overlap* + *local:global: graphemic overlap* + (*1* | *subject*). First fixation durations were significantly shorter in local-biasing contexts (M = 206) relative to local-neutral contexts (M = 214), b = -1.10, SE = 0.05, t = −2.03, p < .05. There was a main effect of global bias which was qualified by a significant interaction with graphemic overlap, b = −0.19, SE = 0.07, t = −2.47, p < .05. In Figure 3 the mean first fixation duration in global neutral and global biasing contexts is plotted as a function of graphemic overlap. To ease

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interpretation, the means for the lowest value, mid value and highest value are plotted. The effect of graphemic overlap follows a U-shaped function, in which the shortest durations are at the midpoint of overlap. This is true for both global-neutral and global-biasing contexts: however, the slopes of the function appear steeper in global-neutral contexts.

Gaze duration

The final model was: *gd* ~ *1 + local + global + local:global + graphemic overlap + local:graphemic overlap + global:graphemic overlap + local:global:graphemic overlap + (1 + global | subject) +(1 | word).* Once again the main effect of global bias was qualified by a significant interaction with graphemic overlap, $b = -0.21$, $SE = 0.09$, $t = -2.46$, $p < .05$, and a U-shaped function of graphemic overlap is again evident (see Figure 3). This time the slopes of the functions are similar across global-neutral and global-biasing contexts. Only that, in the latter case, durations are altogether shorter.

Spillover

The final model was: *Spill* ~ *1 + local + global + local:global + graphemic overlap + local:graphemic overlap + global:graphemic overlap + local:global:graphemic overlap + (1 + local | subject) + (1 | word*). There were no main effects of interactions (all p's > .05).

Total reading time

The final model was: *trt* ~ *1 + local + global + local:global + graphemic overlap + local:graphemic overlap + global:graphemic overlap + local:global:graphemic overlap + (1 | subject) + (1 |word).* The same interaction between global bias and orthographic overlap was again observed in the analyses of total reading time, $b = -0.35$, $SE = 0.11$, $t = -3.07$, $p < .05$. Review of Figure 3 reveals a divergence in the effect of orthographic overlap across global-neutral and global-biasing contexts. Specifically, another U-shaped function is observed for global-neutral contexts. In contrast, in global-biasing contexts, there is a relatively sharp drop in reading times between overlaps of 0.3 to 0.5, followed by a slightly shallower, but still persistent drop to the highest degree of overlap, 0.9.

The key finding from the analyses on the effects of graphemic overlap across the different contextual bias conditions for non-identical cognates revealed a consistent U-shaped pattern in processing time across first fixation, gaze duration and total reading times. This pattern suggests a sort of "sweet spot" or ideal degree of orthographic overlap that appears the least disruptive to processing time. It seems that when the overlap between cognate translations is particularly low the co-activation of its relatively dissimilar cross-language mate may be lessened. When, on the other hand, the overlap is quite high, but not identical, both representations are co-activated more strongly: however, those fine grained distinctions in spelling are sufficient to inflict a cost from competition. At the midpoint of overlap there is sufficient co-activation of both representations: however, the distinctions in form overlap may be sufficient to allow for faster resolution of the competition as they might be more perceptually salient than at the far extreme of overlap. Importantly, these dynamics were more pronounced in global-neutral contexts relative to global-biasing contexts, suggesting an attenuating effect of global context on cross-language lexical activation.

General discussion

The overall goal of the present study was to test whether the presence of a global context influences the extent and/or nature of cross-language lexical activation. Four hypotheses were tested. As a reminder these were (1) context modulates non-selectivity through resonant, top-down activation, (2) context modulates non-selectivity through the generation of lexical feature restrictions, (3) there is a fundamental alteration in the nature of lexical access that eliminates effects of language non-selectivity ("extreme selectivity hypothesis") and, (4) context does not modulate cross-language activation dynamics at all ("extreme non-selectivity hypothesis").

The results from the present study rule out both extreme hypotheses. In terms of the extreme selectivity hypothesis, cognate effects were not eliminated in discourse contexts. Instead, in global-neutral contexts inhibitory effects of cognate status were observed across gaze duration and total reading times. The extreme, non-selective hypothesis is also ruled out because the extent and nature of the cognates effects was in fact modulated across the four different context conditions.

The pattern of cognate effects observed in the present study is consistent with a dual operation of both resonance and feature-restriction mechanisms from context. Consistent with resonance, cognate effects were greater in magnitude in global-neutral relative to global-biasing contexts. In the categorical analyses of cognate status the cost associated with cognate status in gaze duration was statistically reliable in global-neutral contexts only. In the analysis of the non-identical cognates, the effects of orthographic overlap on processing time were consistently greater in magnitude in global-neutral relative to global-biasing contexts. The distinction between global-neutral versus global-biasing context was particularly striking in the total reading time data. Total reading times for non-identical cognates continued to show a U-shaped function in global-neutral contexts, whereas the reading times in global-biasing contexts showed a systematic reduction in reading time with increasing orthographic overlap. This suggests that the bottom-up competitive dynamics from co-activated form were overridden by top-down resonant semantic activation from the global bias.

However, there are several aspects of the results that are not fully accounted for by a strict resonance mechanism. Specifically, if only a resonant mechanism were in operation then the observed cost of cognate status in global-neutral contexts should have been smaller in magnitude when bias was provided at the local level. However, the opposite was observed in both gaze duration and total reading time. Although the 3-way interaction with local context was not statistically reliable, the means plotted in figures 1 and 2 clearly show inflated processing times for cognate relative to noncognates in global neutral/local biasing contexts. This suggests that in local-biasing contexts, more specific, form-feature restrictions were generated, thus producing a larger cost associated with cognate status.

Another key finding from the present study, consistent with recent research on context effects, is the critical modulating role of the degree of orthographic overlap of cognate translations. This is consistent with the findings from Balling (2013) and Cop et al. (2017) in which the magnitude of cognate effects depended on the cross-language similarity in orthographic form. It is also critical to note that completely different conclusions regarding selectivity can emerge depending on whether cognate status is treated continuously or categorically. In the present study, means from the categorical analysis rendered a language-selective like pattern in gaze duration and total reading times in global-biasing contexts. However, when orthographic overlap was treated continuously, evidence supporting non-selectivity

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emerged. Specifically, in global biasing contexts gaze durations and total reading time were in fact affected by the cross-language overlap in orthographic form of the cognates. This is similar to the studies by Duyck and colleagues in which in an earlier publication they did not observe any effects of cognate status for non-identical cognates when they treated cognate status categorically (Duyck et al., 2007). However, in two later studies, when they treated cognates status continuously based on form overlap they observed persistent effects of cognates status in both low- and high-constraint sentence contexts (van Assche et al., 2009, 2012).

A novel and unexpected finding from the present study was the U-shaped function in processing times associated with orthographic overlap. We predicted that cognate effects, whether inhibitory or facilitative in nature would simply increase monotonically as a function of increasing overlap. Instead, processing time was relatively longer at both ends of overlap (0.3 and 0.9), with the shortest times observed at the midpoint. It is striking that this pattern was evident across first fixation, gaze duration and total reading times. We can offer only a preliminary interpretation since this was not predicted a priori. One possibility is that the midpoint represents an ideal balance of similarity that benefits identification without the possible perceptual confusion that might occur for cognates that are highly similar but have small-grained, nuanced differences in their specific spelling. It is important to note that participants were reading in their more dominant language, making it particularly striking that reading times were affected by orthographic representations in a relatively weaker language.

In terms of implications for current theories and models of bilingual reading comprehension, there is not a model of discourse comprehension that specifically addresses the unique cognitive architecture of the bilingual lexicon. The BIA+ (Dijkstra & van Heuven, 2002) is a model of the lexicon and is not intended to capture or account for in detail the differing activation dynamics that emerge from local and global discourse contexts. Nonetheless, the present findings are compatible with the critical assumptions of the BIA+ ; namely, that activation flows non-selectively across an integrated lexicon and that the processing consequence of this co-activation (facilitative versus a cost) depends on the degree of overlap in co-activated orthographic units. Also, resonant activation is a core feature of the architecture of the BIA+. Within the integrated lexicon, bottom-up activation of orthographic and phonological units feedforward to a shared semantic representations, which in turn produces strong top-down resonant activation to its constituent lexical form components.

The fact that the associated cost of cognate status was numerically largest in global-neutral/local-biasing contexts in the present study should be further explored in future research. This specific pattern can only be accommodated by a feature-restriction account. Again, because the three-way interaction was not statistically reliable we can only offer tentative implications here. However the pattern observed in both gaze duration and total reading time should serve as impetus for future work to extend the assumptions of this framework. Specifically, cognates are unique to bilinguals. Monolinguals do not have lexical representations that share semantics and variations of high orthographic overlap; within-language homonyms are, by definition, always form-identical. Previous studies that demonstrated that when lexical feature form restrictions conflict with actual stimulus input there is a processing cost are all based on completely dissimilar words (*money/dinero* in Altarriba et al. (1996); *residents/tenants* in Schwanenflugel and LaCount, 1988; *stairs/mountain* in Schwanenflugel and White (1991). This is the first extension of this framework demonstrating that the form feature restrictions are actually quite precise, so much so that even relatively small differences in the alternative readings of a cognate compete and slow processing. The present study also demonstrates that semantic bias – provided at the local level, in particular – is more likely to lead to the generation of such specific form feature restrictions.

As reviewed earlier, in the original publication of the BIA+ the authors accommodated the assumptions of the feature restriction account in their postulation of how a semantic context might affect non-selectivity (Dijkstra & van Heuven, 2002). However, it remains unspecified where the locus of such feature restrictions would reside. This is understandable as it is a model of the lexicon and not discourse comprehension.

It is clear that bilingual reading comprehension involves an additional level of lexical competitive dynamics. These add dynamics requiring a higher degree of reading skill and lexical knowledge if bilingual reading is to be directly compared to monolingual reading or expected to be similar in performance and execution. It is particularly important to note that, in the present study, the typically-observed benefits of discourse semantic bias were not observed for cognates with less orthographic similarity. This underscores the fact that bilingual reading is not the same as monolingual reading. A strong, empirical research base is needed in the hopes that this information will shape not only theorizing but also pedagogical practices.

Supplementary Material. For supplementary material accompanying this paper, visit http://dx.doi.org/10.1017/S136672892100016X

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