Journal of Experimental Psychology:
Learning, Memory, and Cognition
2009, Vol. 35, No. 2, 381–390

0278-7393/09/$12.00 DOI: 10.1037/a0014875

Bilingual Lexical Access in Context: Evidence From Eye Movements During Reading

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Current models of bilingualism (e.g., BIA+) posit that lexical access during reading is not language selective. However, much of this research is based on the comprehension of words in isolation. The authors investigated whether nonselective access occurs for words embedded in biased sentence contexts (e.g., A. I. Schwartz & J. F. Kroll, 2006). Eye movements were recorded as French–English bilinguals read English sentences containing cognates (e.g., *piano*), interlingual homographs (e.g., *coin,* meaning corner in French), or matched control words. Sentences provided a low or high semantic constraint for target-language meanings. Both early-stage comprehension measures (e.g., first fixation duration, gaze duration, and skipping) and late-stage comprehension measures (e.g., go-past time and total reading time) showed significant cognate facilitation and interlingual homograph interference for low-constraint sentences. For high-constraint sentences, however, only early-stage comprehension measures were consistent with nonselective access. There was no evidence of cognate facilitation or interlingual homograph interference for late-stage comprehension measures. Thus, nonselective bilingual lexical access at early stages of comprehension is rapidly resolved in semantically biased contexts at later stages of comprehension.

Keywords: bilingualism, eye tracking, sentence processing, interlingual homographs, cognates

A fundamental question regarding bilingualism is whether the bilingual lexicon has a language-specific organization (having independent or modular memory stores for each known language) or a language-nonspecific organization (having an integrated memory store containing all known words in both languages). These views of bilingualism translate to different predictions regarding real-time language processing. A language-specific view predicts that separate language stores may be selectively accessed. Conversely, a language-nonspecific view predicts that representations from both languages are accessed simultaneously during comprehension. This latter view comprises the nonselective access position.

Investigations using words that are similar across languages have been pivotal for testing between selective versus nonselective models of bilingualism. For example, interlingual homographs have identical orthographic forms but distinct meanings across two languages (e.g., *chat*—casual talk in English, cat in French). Cognates have overlapping orthographic and semantic representations between languages (e.g., *film* and *piano,* which are identical in English and French).

Many studies examining these words favor the nonselective access view (e.g., De Groot & Nas, 1991; Dijkstra, De Bruijn, Schriefers, & Brinke, 2000; Dijkstra, Van Jaarsveld, & Ten Brinke, 1998). Across a variety of tasks and languages, bilinguals typically show interference for interlingual homographs and facilitation for cognates, compared with monolingual control words (but see also Dijkstra, Grainger, & Van Heuven, 1999). Interference effects for interlingual homographs are thought to arise because lexical activation of target and nontarget language representations diverge onto two separate meanings and thus impede comprehension. Facilitation effects for cognates are thought to arise because lexical activation of target and nontarget language representations converge onto the same meaning and thus speed comprehension.

Our understanding of nonselective access in bilinguals comes almost exclusively from studies where words such as interlingual homographs and cognates are presented in isolation. However, on the basis of the monolingual literature, it is clear that lexical ambiguity resolution is influenced by the nature of the surrounding sentence context. For example, using eye tracking methodology, Duffy, Kambe, and Rayner (2001) demonstrated that activation of an ambiguous word's multiple meanings is dependent upon the relative frequency of the meanings and contextual support provided by the surrounding sentence. These and other findings (e.g., Binder & Morris, 1995) directly support the reordered access model of sentence processing. According to this model, the relative speed of lexical activation, as determined by meaning frequency, can be reordered by the semantic information provided by a sentence context. The constraining effect of context on lexical activation has significant impli-

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Maya R. Libben gratefully acknowledges support from a Natural Sciences and Engineering Research Council of Canada (NSERC) doctoral fellowship. Debra A. Titone acknowledges support from an NSERC Discovery Award, the Canada Research Chairs Program, and the Canadian Foundation for Innovation.

We would like to thank Nathalie Belanger, Luciana Gravotta, Evgenia Berger, and Marie Duan for their assistance with this study. We are grateful to Keith Rayner, Tamar Gollan, and Wouter Duyck for comments on the manuscript.

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cations for nonselective models of bilingual language processing; however, only a handful of empirical studies have investigated how sentence context affects bilingual lexical access.

Van Hell (1998) investigated this issue by having highly proficient Dutch–English bilinguals read high- or low-constraint sentences where a target word (e.g., *apple*) was replaced by dashed lines (e.g., *A green —— and a yellow banana lay on the fruit dish*). Subsequent to sentence presentation, participants made a lexical decision to an isolated target consisting of a cognate or a control word. Van Hell found facilitation for cognates in low-constraint sentences, but not high-constraint sentences. These results suggest that nonselective lexical access is modulated by the amount of contextual information provided by the sentence.

Schwartz and Kroll (2006) found similar results for Spanish–English bilinguals using a rapid serial visual presentation (RSVP) task. Participants were presented with interlingual homographs, cognates, or matched control words embedded in high- and low-semantic-constraint sentences. Naming latency of the target word was taken to reflect the speed of lexical access. Consistent with Van Hell (1998), cognate facilitation was observed only for low-constraint sentences. Interestingly, naming latencies for interlingual homographs did not differ from matched control words regardless of context, a finding that is inconsistent with earlier studies of interlingual homographs presented in isolation (e.g., Beauvillain & Grainger, 1987; Dijkstra & Van Heuven, 2002). The authors noted that the lack of significant homograph effects may have been due to the relative insensitivity of the RSVP task.

Using an arguably more sensitive task, Duyck, Van Assche, Drieghe, and Hartsuiker (2007) had Dutch–English bilinguals read sentences in a normal fashion for comprehension while their eye movements were monitored. Duyck et al. compared processing of cognates that were form identical (e.g., *film*) or nonidentical (e.g., *banaan–banana*) for low-semantic-constraint sentences (interlingual homographs were not studied). Measures of first fixation, gaze duration, and total reading time for target words revealed facilitation for form-identical cognates only. Form-nonidentical cognates were read comparably to control words. These results corroborate previous findings of nonselective access for cognates in low-semantic-constraint sentences and highlight the importance of cross-language orthographic overlap. However, they do not address possible effects of semantic constraint.

Thus, the present study investigated this issue by examining the effects of semantic constraint on nonselective access for both interlingual homographs and cognates using eye movement recordings during reading. Eye movement studies of language have important advantages over standard cognitive tasks such as semantic priming (Rayner, 1998). First, reading for comprehension is a natural process and requires no overt decisions. Second, the time course of comprehension may be evaluated with different dependent measures derived from the same task and participants. Thus, we can obtain information about the time course of bilingual lexical access as a function of semantic constraint.

Method

Participants

Thirty McGill University (Montreal, Quebec, Canada) undergraduate students participated either for course credit or for compensation at a rate of $10/hour Canadian (approximately $8.50 U.S. during period of testing). Participants were highly proficient, French-dominant, French–English bilinguals. All participants performed the task in their second language (i.e., English). French-dominant bilinguals were recruited preferentially to maximize the probability of observing nonselective access in the low-contextual-constraint condition (De Groot & Nas, 1991; Von Studnitz & Green, 2002). Participants had normal or corrected-to-normal vision and no self-reported speech or hearing disorders.

Participants completed a language history questionnaire modeled after the Language Experience and Proficiency Questionnaire (LEAP-Q; Marian, Blumenfeld, & Kaushanskaya, 2007). The results are summarized in Table 1. All participants reported learning French as their first language and rated French as their dominant language at the time of testing.

Materials

Target words consisted of 32 French–English interlingual homographs (e.g., *coin*) and 32 French–English form-identical cognates (e.g., *piano*). Interlingual homograph and cognate status was verified by five French–English bilinguals who did not participate in the reading experiment. We specifically selected interlingual homographs whose French frequency was higher than or equal to the English frequency to again maximize the probability of observing nonselective access in the low-constraint condition (Dijkstra et al., 1998).

English control words were selected using WordGen (Duyck, Desmet, Verbeke, & Brysbaert, 2004) and were individually matched with the interlingual homographs and cognates for word length, frequency, and neighborhood density (see Table 2).

Table 1
Self-Assessed English Proficiency Ratings and Language History (N = 29)

Proficiency measure	Minimum	Maximum	Mean
Rating scales (0–10)			
Speaking Ability	5	10	7.72
Reading Ability	6	10	8.07
Writing Ability	4	10	7.59
Translating Ability	4	10	7.24
Listening Comprehension	6	10	8.04
Pronunciation	4	10	7.24
Fluency	6	10	6.90
Grammatical Ability	5	10	7.66
Overall Competence	6	10	7.79
Sum of rating scales (0–100)	57	100	76.52
Age of acquisition (years old)			
Began acquiring English	0	12	7.52
Became competent in English	5	21	13.75
Began reading in English	6	16	10.54
Became competent in reading English	9	18	14.64
Degree of French interference when functioning in English (0–5)			
Speaking	1	5	1.90
Reading	1	5	2.93
Percentage of present time spent functioning in each language			
English	10	95	50.10
French	5	90	47.24

Table 2
Word Length, Mean Frequency (Log), and Neighborhood Density of Interlingual Homographs, Cognates, and Matched Controls

	English			French	
Word type	Number of letters	Frequency	Neighborhood density	Frequency	Neighborhood density
Homographs	4.48	1.10	8.26	1.90	7.07
Homograph controls	4.59	1.09	7.93		
Cognates	6.39	1.49	1.34	1.55	1.35
Cognate controls	6.39	1.43	1.42		

Two types of sentences were created for each target word and the matched control words. All sentences had a two-clause structure. The first clause was semantically biased toward the target word (high-semantic-constraint) or was semantically unbiased toward the target word (low-semantic-constraint). The second clause contained a target word or matched control word in a nonsentence-final position. Thus, each item was associated with four total sentences (high- and low-constraint sentences for the target and its matched control word; see Table 3).[1] The sentences for each item were created to be as similar as possible between targets and matched control words (see Table 4). Target and control words were always preceded by an identical word greater than five characters to minimize skipping of the target during reading.

The degree of semantic constraint for the sentences was quantified using two normative procedures. In the sentence rating task, 12 monolingual English participants were instructed to judge whether the initial sentence clause biased the target word on a 10-point scale (10 = *high-constraint*). Two interlingual homograph sets and one cognate set were removed from all subsequent analyses due to semantic constraint ratings below 6 in the high-constraint condition. In addition, three interlingual homograph sets were removed because their control words were French–English cognates. Thus, our analyses are based on 27 interlingual homographs and 31 cognates (see Table 5).

High-semantic-constraint sentences were rated as significantly more biasing than low-semantic-constraint sentences for all target and control words, cognates: $t(30) = 33.46$, $p < .01$; cognate controls: $t(30) = 40.72$, $p < .01$; homographs: $t(26) = 19.30$, $p < .01$; homograph controls: $t(26) = 26.52$, $p < .01$. There were no significant differences in the ratings between the target and control words for low-semantic-constraint sentences or for high-semantic-constraint sentences.

We also conducted a cloze probability test where 60 English speakers completed sentences with the target word omitted (e.g., *He wanted to ward off vampires, so the strong smelling ____ was everywhere*). Similar to the ratings results, cloze probability for high-semantic-constraint sentences was significantly higher than for low-semantic-constraint sentences for all target and control words, homographs: $t(26) = 6.29$, $p < .01$; homograph controls: $t(26) = 5.4$, $p < .01$; cognates: $t(30) = 8.05$, $p < .01$; cognate controls: $t(30) = 7.91$, $p < .01$ (see Table 5). Cloze probability did not differ significantly for the target and control words for low-semantic-constraint sentences or for high-semantic-constraint sentences.

The four sentence conditions were counterbalanced across two lists such that each participant saw both the critical word (e.g., *province*) and its matched control word (e.g., *mushroom*), but in different sentence contexts. One word was presented in a high-constraint sentence (e.g., *After trying a Portobello last year, it became her favorite mushroom because of its taste*), and the other was presented in a low-constraint sentence (e.g., *After her visit to the west last year, it became her favorite province because of the culture*). Thus, there were a total of 128 observations per condition for each participant, 116 of which were included in the final analyses.

Yes–no comprehension questions occurred on 25% of trials to ensure participants read for content (e.g., *Having been created by a perfectionist, the detailed photo had turned out well*. Question: *Was the photo of good quality?*).

Language proficiency assessment. Objective reading proficiency was also assessed using eye movement recording measures generated while participants read English and French paragraphs (see Altarriba, Kroll, Sholl, & Rayner, 1996). Two paragraphs that had been directly translated in English and French were selected from the government of Canada Web site (www.canada.gc.ca). Each participant read one passage in English and a different passage in French. The order of presentation of French and English paragraphs was counterbalanced. Following each passage, participants answered three comprehension questions.

Apparatus

Eye movement data were acquired using an Eye-Link 1000 tower mounted system (SR-Research, Ontario, Canada) with a sampling rate of 1 kHz. Viewing was binocular, but eye movements were recorded from the right eye only.

Procedure

Participants completed the sentence reading task first, followed by the paragraph reading and language history questionnaire. Participants were told that they would read sentences on a computer screen for comprehension while their eye movements were monitored. Each sentence was presented on a single line in cyan blue 14-point New Courier font on a black background. Participants were instructed to read at their normal speed and press a button when they had finished reading the sentence. They were told that following some trials, they would encounter a simple comprehen-

[1] The full set of stimulus sentences can be obtained by contacting Debra A. Titone.

Table 3
Sample Sentences Across Conditions

Word type	Low-constraint sentence	High-constraint sentence
Interlingual homographs		
Target word	Since they really liked each other, they had an extended *chat* that lasted all night.	Since they liked to gossip, they had an extended *chat* that lasted all night.
Matched control	Since he was kind of bored, he made an extended *tune* that was very catchy.	Since he liked to compose songs, he made an extended *tune* that was very catchy.
Cognates		
Target word	Because they owned a lot of property around the world, the expensive *divorce* was a disaster.	Because of the bitter custody battle over the kids, the expensive *divorce* was a disaster.
Matched control	Because her parents strongly disapproved of her decision, the expensive *wedding* was a disaster.	Because the maid of honor and best man were late, the expensive *wedding* was a disaster.

sion question and were to respond yes or no using the appropriate buttons on a control pad. Calibration consisted of a standard five-point grid. Following initial calibration, participants were given 10 practice trials to become familiar with the procedure before reading the experimental sentences. Participants encountered a total of 128 experimental sentences presented in random order. Rest breaks were provided as needed. None of the participants reported noticing that French–English interlingual homographs and cognates were embedded in the sentences during experimental debriefing.

Following the reading task, participants were instructed to read two paragraphs on the computer screen while their eye movements were monitored. They were told that one passage would be in English and one in French and that they would answer three comprehension questions relating to each passage after they had finished reading. Paragraphs were presented in cyan blue New Courier 14-point font on a black background. Participants were instructed to read at a normal rate and to press a button when they had finished reading each paragraph.

In the final portion of the experiment, participants completed the language history questionnaire. The questionnaire was administered on Internet-based software (www.surveymonkey.com).

Results

Of the 30 participants, one was excluded from all subsequent analyses because of poor performance (<75%) on the sentence reading comprehension questions.

We examined both early and late eye tracking measures of comprehension (Rayner, 1998). Early measures included first fixation duration, first pass gaze duration, and skipping rate, which are assumed to reflect initial lexical access. Later stage measures included go-past time and total reading time, which are assumed to reflect higher order processes such as semantic integration, revision, and ambiguity resolution. Definitions for each of the above eye tracking measures are provided in Table 6.

We removed 4.57% of the data from our analyses because of track loss or because fixation durations were shorter than 100 ms. We computed a series of 2 (word type: critical word vs. matched control) $\times$ 2 (sentence type: high-constraint vs. low-constraint) repeated measures analyses of variance (ANOVAs) for interlingual homographs and cognates separately, for each dependent measure. Statistics for the ANOVA analyses are provided in Table 7. Descriptive results for interlingual homographs and cognates are summarized in Table 8. Finally, Table 9 presents the results of simple effect analyses comparing target words and matched controls across both high- and low-constraint sentences, also reflected in the difference scores in Table 8.

Interlingual Homographs

First fixation duration. Analysis revealed a main effect of sentence constraint where target words in high-constraint sentences received significantly shorter fixations (M = 270.75) than target words in low-constraint sentences (M = 330.55). We also found a main effect of word type where first fixations to interlingual homographs were significantly longer (M = 310.17) than to

Table 4
Sentence Length, Position of Target Word, and Length of the Word Preceding the Target Word for High- and Low-Constraint Stimulus Sentences for Interlingual Homographs, Cognates, and Matched Control Words

Target-word type	Sentence constraint	Sentence length (number of words)	Position of target word (nth word)	Length of Word $n - 1$ (number of characters)
Interlingual homograph	High	15.48	11.45	8.12
	Low	15.22	11.32	8.12
Interlingual homograph control	High	15.85	11.51	8.10
	Low	15.44	11.43	8.10
Cognate	High	14.19	10.11	7.96
	Low	14.61	10.32	7.96
Cognate control	High	14.61	10.32	7.96
	Low	14.52	10.23	7.96

Table 5
Mean Semantic Biasing Ratings and Cloze Probabilities for Target Words for All Sentence Conditions

Word type	Biasing ratings (0–10)		Cloze probability (0–1)	
	High constraint	Low constraint	High constraint	Low constraint
Interlingual homograph	8.34	2.90	.40	.04
Interlingual homograph control	8.53	2.87	.37	.02
Cognate	8.86	3.05	.48	.04
Cognate control	8.85	2.82	.49	.04

matched control words (M = 291.13). The interaction between word type and sentence constraint was not significant.

First pass gaze duration. Similar to the results for first fixation duration, there was a main effect of sentence constraint where target words in high-constraint sentences received significantly shorter first pass reading times (M = 293.29) than words in low-constraint sentences (M = 357.12). A main effect of word type suggested that reading time was longer for interlingual homographs (M = 375.74) compared with matched control words (M = 304.31). The interaction between word type and sentence constraint was not significant.

Proportion of skipped targets. A main effect of sentence constraint suggested that target words in high-constraint sentences were skipped significantly more often (M = 0.10) than words in low-constraint sentences (M = 0.06). Interlingual homographs and matched control words did not differ significantly in skipping rates. The interaction between word type and sentence constraint was not significant.

Go-past time. Analysis revealed a significant interaction between word type and sentence constraint. Planned comparisons revealed that interlingual homographs and their matched controls did not differ significantly for high-constraint sentences (interlingual homographs: M = 380.63; control: M = 388.22). However, significantly more time was spent reading interlingual homographs (M = 485.57) compared with matched controls (M = 418.30) for low-constraint sentences.

Total reading time. Analysis revealed a significant interaction between word type and sentence constraint. Planned comparisons revealed that interlingual homographs and matched controls did not differ for high-constraint sentences (interlingual homographs: M = 472.46; control: M = 475.97), but reading times for interlingual homographs were significantly longer than controls for low-constraint sentences (interlingual homographs: 608.09; control: 491.11).

Cognates

Across the various dependent measures, results for cognates generally mirrored those of interlingual homographs, but instead of interference, cognates exhibited facilitation when compared with matched control words.

First fixation duration. There was a main effect of sentence constraint where target words in high-constraint sentences received significantly shorter first fixation durations (M = 246.12) than those in low-constraint sentences (M = 316.17). There was a main effect of word type where first fixation durations to cognates were significantly shorter (M = 267.79) than those to matched control words (M = 294.50). The interaction between word type and sentence constraint was not significant.

First pass gaze duration. There was a main effect of sentence constraint where target words in high-constraint sentences received shorter first pass reading times (M = 280.35) than words in low-constraint sentences (M = 347.04). A main effect of word type was also found in that reading time was shorter for cognates (M = 294.92) than for matched control words (M = 332.47). The interaction between word type and sentence constraint was not significant.

Proportion of skipped targets. There was a main effect of sentence constraint suggesting that target words in high-constraint sentences were skipped significantly more often (M = 0.04) than words in low-constraint sentences (M = 0.01). The main effect of word type was restricted to the subject analysis, where cognates were skipped more often (M = 0.04) than matched control words (M = 0.02). The interaction between word type and sentence

Table 6
Definitions for Early Eye Tracking Measures, Including First Fixation Duration, First Pass Gaze Duration, and Skipping, as Well as Late-Stage Measures Such as Go-Past Time and Total Reading Time

Stage	Eye tracking measure	Definition
Early	First fixation duration	The length of time the eyes fixate on the target word the first time they land on it
	First pass gaze duration	The sum of all fixation durations starting the moment the eyes land on the target word until the moment they move away
	Skipping	The proportion of trials where the target word is not fixated
Late	Go-past time	The sum of all fixation durations starting the moment the eyes first land on the target word until they make a rightward saccade past the target word
	Total reading time	The sum of all fixations and refixations on the target word during a given trial

Table 7
The Results of 2 (Word Type: Critical Word Vs. Matched Control) × 2 (Sentence Type: High-Constraint Vs. Low-Constraint) Repeated Measures Analyses of Variance for Interlingual Homographs and Cognates

			Subject analysis			Item analysis		
Word type	Measure	Effect	*df*	F1 value	*p* value	*df*	F2 value	*p* value
Interlingual homograph	First fixation	Word type	(1, 28)	10.97	<.01	(1, 26)	7.85	.01
		Sentence type	(1, 28)	84.90	<.01	(1, 26)	141.55	<.01
		Interaction	(1, 28)	0.08	*ns*	(1, 26)	0.06	*ns*
	First pass gaze duration	Word type	(1, 28)	16.71	<.01	(1, 26)	11.58	<.01
		Sentence type	(1, 28)	59.92	<.01	(1, 26)	83.85	<.01
		Interaction	(1, 28)	0.74	*ns*	(1, 26)	0.50	*ns*
	Skipping	Word type	(1, 28)	0.46	*ns*	(1, 26)	0.21	*ns*
		Sentence type	(1, 28)	5.36	<.05	(1, 26)	5.54	<.05
		Interaction	(1, 28)	0.24	*ns*	(1, 26)	0.22	*ns*
	Go-past time	Word type	(1, 28)	12.78	<.01	(1, 26)	3.38	*ns*
		Sentence type	(1, 28)	29.38	<.01	(1, 26)	24.50	<.01
		Interaction	(1, 28)	12.39	<.01	(1, 26)	7.61	.01
	Total reading time	Word type	(1, 28)	17.20	<.01	(1, 26)	4.94	<.05
		Sentence type	(1, 28)	26.92	<.01	(1, 26)	13.69	<.01
		Interaction	(1, 28)	31.89	<.01	(1, 26)	15.43	<.01
Cognate	First fixation	Word type	(1, 28)	25.07	<.01	(1, 30)	17.83	<.01
		Sentence type	(1, 28)	119.33	<.01	(1, 30)	88.51	<.01
		Interaction	(1, 28)	1.33	*ns*	(1, 30)	2.23	*ns*
	First pass gaze duration	Word type	(1, 28)	37.86	<.01	(1, 30)	29.12	<.01
		Sentence type	(1, 28)	89.42	<.01	(1, 30)	104.10	<.01
		Interaction	(1, 28)	0.06	*ns*	(1, 30)	0.08	*ns*
	Skipping	Word type	(1, 28)	4.67	<.05	(1, 30)	3.24	*ns*
		Sentence type	(1, 28)	21.44	<.01	(1, 30)	28.77	<.01
		Interaction	(1, 28)	1.33	*ns*	(1, 30)	2.79	*ns*
	Go-past time	Word type	(1, 28)	17.93	<.01	(1, 30)	9.77	<.01
		Sentence type	(1, 28)	18.76	<.01	(1, 30)	5.92	<.05
		Interaction	(1, 28)	34.85	<.01	(1, 30)	10.30	<.01
	Total reading time	Word type	(1, 28)	11.61	<.01	(1, 30)	8.79	<.01
		Sentence type	(1, 28)	41.64	<.01	(1, 30)	15.22	<.01
		Interaction	(1, 28)	13.97	<.01	(1, 30)	4.92	<.05

Note. F1 = subject analysis; F2 = item analysis.

constraint was not significant. However, planned comparisons showed that cognates were skipped significantly more often only in the high-constraint condition.

Go-past time. There was a significant interaction between word type and sentence constraint for go-past time. Planned comparisons revealed that cognates and their matched controls did not differ significantly for high-constraint sentences (cognates: M = 385.11; control: M = 392.38). However, reading times for cognates were significantly shorter (M = 388.06) than for matched controls (M = 473.87) for low-constraint sentences.

Total reading time. A significant interaction between word type and sentence constraint was found for total reading time.

Table 8
Mean Values and Difference Scores for First Fixation Duration (FFD), First Pass Gaze Duration (GD), Skipping Proportion (Skip), Go-Past Time (GPT), and Total Reading Time (TRT) for Interlingual Homographs, Cognates, and Matched Control Words

	FFD		GD		Skip		GPT		TRT	
Word type	High constraint	Low constraint	High constraint	Low constraint	High constraint	Low constraint	High constraint	Low constraint	High constraint	Low constraint
Interlingual homograph										
Target	279	341	304	376	0.09	0.06	381	486	472	608
Control	262	320	282	339	0.11	0.06	388	418	476	491
Difference	17	21*	22*	37**	−0.02	0	−8	67**	−4	117**
Cognate										
Target	229	307	261	329	0.06	0.01	385	388	458	505
Control	263	326	300	365	0.03	0.01	392	474	464	600
Difference	−34**	−19**	−39**	−36**	0.03*	0	−7	−86**	−6	−95**

* Planned comparison significant at the .05 level. ** Planned comparison significant at the .01 level.

Table 9
Planned Comparisons (One-Tailed) Investigating Word Type Effects (i.e., Target Vs. Control) Across Sentence Constraint Conditions

Word type	Eye tracking measure	Sentence constraint	Subject analysis			Item analysis		
			df	*t* value	*p* value	*df*	*t* value	*p* value
Interlingual homograph	First fixation	High	28	−1.73	.05	26	−1.69	.05
		Low	28	−2.40	.01	26	−2.09	<.05
	First pass gaze duration	High	28	−2.15	<.05	26	−2.15	<.05
		Low	28	−3.00	<.01	26	−3.11	<.01
	Skipping	High	28	0.70	*ns*	26	0.70	*ns*
		Low	28	0.27	*ns*	26	0.03	*ns*
	Go-past time	High	28	0.57	*ns*	26	0.35	*ns*
		Low	28	−4.91	<.01	26	−4.07	<.01
	Total reading time	High	28	0.26	*ns*	26	0.15	*ns*
		Low	28	−5.78	<.01	26	−4.35	<.01
Cognate	First fixation	High	28	3.76	<.01	30	3.87	<.01
		Low	28	2.50	<.05	30	2.60	.01
	First pass gaze duration	High	28	4.16	<.01	30	4.08	<.01
		Low	28	4.59	<.01	30	4.57	<.01
	Skipping	High	28	−2.28	<.05	30	−1.84	<.05
		Low	28	−0.37	*ns*	30	−0.34	*ns*
	Go-past time	High	28	0.73	*ns*	30	0.30	*ns*
		Low	28	5.63	<.01	30	4.56	<.01
	Total reading time	High	28	0.43	*ns*	30	0.61	*ns*
		Low	28	4.23	<.01	30	3.81	<.01

Planned comparisons revealed that total reading time for cognates and matched controls did not differ for high-constraint sentences (cognates: M = 457.84; control: M = 464.29), but reading times for cognates were significantly shorter when embedded in low-constraint sentences (cognates: M = 504.72; control: M = 599.94).

Language Proficiency

Results from the paragraph reading task were consistent with participants' self-reports on the LEAP-Q. Average fixation durations for the English paragraph were significantly longer (M = 230.11) than those for the French paragraph (M = 216.62), $t(28)$ = 3.66, $p < .01$. Furthermore, the summed score for English proficiency ratings in the questionnaire correlated significantly with the calculated difference between average English fixation duration and French fixation duration ($r = .56$, $p < .01$) during paragraph reading. Specifically, participants with higher self-reported proficiency in English showed less of a difference between their English (L2) and French (L1) reading patterns.

The relationship between participants' English proficiency and degree of interlingual homograph interference and cognate facilitation was investigated by correlations between self-reported English proficiency ratings and objective paragraph reading measures, with difference scores between both interlingual homographs and cognates and their matched controls on the eye tracking measures reported above. We found no clear relationship between level of interlingual homograph inhibition and L2 proficiency (see Table 10). However, correlation coefficients for cognates, provided in Table 11, suggest that participants who were more proficient in their L2 (i.e., English) showed a global decrease in cognate facilitation. Moreover, for first fixation duration, the trend toward smaller cognate effects for more proficient bilinguals occurred only for high-constraint sentences. However, a mixed model analysis revealed that the interaction between English proficiency ratings and sentence type missed significance ($p = .09$).

General Discussion

We used eye movement recordings during reading to investigate whether nonselective lexical access in bilinguals is modulated sentential constraint. French–English interlingual homographs (e.g., *coin*) and cognates (e.g., *piano*) were embedded in English sentences that provided either a high- or low-semantic-constraint for target-language meanings.

Analysis of early comprehension measures (first fixation, first pass gaze duration, and skipping rate) revealed that interlingual homographs were generally read more slowly than matched control words in both low- and high-constraint sentences. The pattern was similar for cognates except that they showed facilitation, consistent with findings reported by Duyck et al. (2007). Thus, immediately upon fixating a word to approximately 350 ms later, lexical access was nonselective and was not affected by a biasing sentence context, although reading for all words was facilitated in highly constrained sentence contexts. In contrast, in the time range of approximately 350–600 ms after first fixating a word, later comprehension measures (e.g., go-past time and total reading time) showed interlingual homograph inhibition and cognate facilitation for low-constraint contexts only. Both interlingual homographs and cognates were comparable to matched control words in high-constraint contexts during this time period, suggesting that only the contextually relevant meaning remained activated.

The late-stage comprehension results (go-past-time and total reading time) may be interpreted with respect to previous studies of sentence context on bilingual lexical access, which used tasks that arguably reflect comprehension processes subsequent to lexical access. The late-stage comprehension data are consistent with

Table 10

Correlation for Participants' Self-Reported English Proficiency Ratings (Sum of 10 Scales Resulting in a Total Score Between 0 and 100) and Objective Paragraph Reading Times (Average Fixation Duration to Words in the English Paragraph Minus the French Paragraph) With Interlingual Homograph Interference Effects (Interlingual Homograph Minus Matched Target) for Measures of First Fixation Duration (FFD), First Pass Gaze Duration (GD), Skipping Proportion (Skip), Go-Past Time (GPT), and Total Reading Time (TRT) in High-Constraint and Low-Constraint Sentences

	Interlingual homograph interference (interlingual homograph − matched control)									
	FFD		GD		Skip		GPT		TRT	
Proficiency measure	High constraint	Low constraint	High constraint	Low constraint	High constraint	Low constraint	High constraint	Low constraint	High constraint	Low constraint
English proficiency rating (scale = 0–100)	−.15	.09	−.23	−.07	.06	.08	−.19	−.10	−.21	−.23
Paragraph fixation duration (English − French)	.20	−.11	.16	.13	−.02	−.02	.12	.08	.23	.18

the lexical decision results for cognates obtained by Van Hell (1998), where cognate facilitation was not observed for high-constraint sentence contexts. They are also consistent with Schwartz and Kroll (2006), who found cognate facilitation for naming in low-constraint but not high-constraint sentences.

Unlike the present study, Schwartz and Kroll (2006) did not find interlingual homograph interference for any sentence context. However, the RSVP naming task may have been less sensitive than eye movement recordings in terms of detecting interlingual homograph interference. Moreover, Schwartz and Kroll did not report how their interlingual homographs varied in word frequency. It is possible that we obtained interlingual homograph interference because of matching target and control words individually for frequency, length, and neighborhood density and selecting interlingual homographs that were balanced or higher frequency in French than English.

In the present study, we assessed language proficiency using both subjective questionnaire ratings and objective measures of eye movements during English and French paragraph reading. These measures correlated highly with one another ($r = .56$) and were analyzed with respect to nonselective access during the main sentence reading task. We found that participants who were more proficient in English, their second language, generally showed less cognate facilitation as compared with French-dominant bilinguals who were not as proficient in English. With respect to first fixation duration, we found an interaction between proficiency and sentence constraint in that highly proficient bilinguals showed reduced cognate facilitation only in high-constraint sentences, as well as a trend suggesting that the additive effect of semantic constraint and proficiency may promote a greater degree of language selectivity at the initial stages of lexical access.

In contrast to the relationship between cognate facilitation and second-language proficiency however, there was no relationship between interlingual homograph interference and second-language proficiency. This may have occurred because of a restricted range in the interlingual homograph data as compared with the cognate data. Interlingual homographs tended to be shorter and higher in frequency than the cognates in this study, a difference that seems to reflect distributional properties of these types of words in French and English. Indeed, inspection of Table 7 shows that the magnitude and range of cognate facilitation were much greater than those of interlingual homograph interference.

Taken together, the results of this study are largely consistent with models of bilingual language processing and the BIA+ model

Table 11

Correlation for Participants' Self-Reported English Proficiency Ratings (Sum of 10 Scales Resulting in a Total Score Between 0 and 100) and Objective Paragraph Reading Times (Average Fixation Duration to Words in the English Paragraph Minus the French Paragraph) With Cognate Facilitation Effects (Cognate Minus Matched Target) for Measures of First Fixation Duration (FFD), First Pass Gaze Duration (GD), Skipping Proportion (Skip), Go-Past Time (GPT), and Total Reading Time (TRT) in High-Constraint and Low-Constraint Sentences

	Cognate facilitation (cognate − matched control)									
	FFD		GD		Skip		GPT		TRT	
Proficiency measure	High constraint	Low constraint	High constraint	Low constraint	High constraint	Low constraint	High constraint	Low constraint	High constraint	Low constraint
English proficiency rating (scale = 0–100)	.45*	−.07	.48**	.43*	−.26	−.18	.41*	.38*	.42*	.46*
Paragraph fixation duration (English − French)	−.40*	.06	−.38*	−.51**	−.02	.08	−.34	−.39*	−.40*	−.41*

* Correlation is significant at the .05 level (two-tailed). ** Correlation is significant at the .01 level (two-tailed).

(Dijkstra & Van Heuven, 2002) in particular. Critically, the BIA+ model assumes that initial lexical activation is nonselective and that the surrounding sentence context can feed back semantic information to the orthographic level. These assumptions are supported by our interlingual homograph findings showing no interference effect in low-constraint sentences and reduced interference for high-constraint sentences for later stage comprehension measures. As predicted by BIA+, semantic constraint for language-relevant meanings at the semantic level feeds back to the orthographic level, thus reducing the amount of observed interference. In the case of interlingual homographs, reduced interference in high-constraint contexts may be accomplished solely on the basis of semantic feedback given that there are distinct semantic representations associated with each lexical form of the interlingual homograph.

An issue that is problematic for BIA+ and bilingual theories in general is how a semantic context can reduce facilitation for cognates given that increased semantic constraint would activate the cognates' orthographic and semantic representations in each language. Semantic to orthographic feedback within BIA+ cannot account for the reduced cognate facilitation found in this and other studies (e.g., Schwartz & Kroll, 2006; Van Hell, 1998). We believe that to account for contextual effects on cognate facilitation, additional assumptions regarding the role of semantic constraint on lexical expectations are necessary. For example, according to monolingual theories addressing sentence context effects, such as the reordered access model, the activation time course of an ambiguous word is dependent upon the relative frequency of the meanings as well as contextual support that is provided in the surrounding sentence (Duffy et al., 2001). In the case of cognates, where semantic representations overlap across languages, there is no competition between disparate semantic representations. Therefore, the attenuation of cognate facilitation in high-constraint conditions may be due to the overlapping feature restrictions imposed by the sentence whereby lexical access is speeded to a point where facilitation can no longer take effect (see also Duyck et al., 2007).

Thus, we propose a view similar to that of Altarriba et al. (1996), where highly constrained sentence contexts lead to increased activation for related material at the semantic level as well as increased lexical expectations at the orthographic level. Heightened lexical expectations at the orthographic level may preactivate the language nodes (Schwartz & Kroll, 2006) and/or propagate selective activation of the interconnected lexical forms belonging to a specific language (Grosjean, 1997). Applied to the present study, lexical expectations driven by semantic feature restrictions cause initial nonselective access (as seen in measures such as first fixation duration) to become more selective during later stages of comprehension (such as go-past time and total reading time).

Given that BIA+ posits that the orthographic level is blind with respect to language membership and that language nodes exist late in the word recognition stream with no direct connections to orthography, it is unclear how this model can account for contextually constrained lexical expectations. As suggested by Schwartz and Kroll (2006), the incorporation of a feedback mechanism from the language nodes to the orthographic level would allow the BIA+ model to account for the attenuation of cognate facilitation in high-constraint contexts. Another possibility is that any phonological discrepancy in cross-language cognate representation may play a role in reducing the cognate facilitation effect in context. If the lexical expectancies generated by biased sentence contexts include phonological as well as orthographic expectancies, one could imagine a feedback mechanism from phonology to orthography (or an indirect path via semantics) that might suppress cognate facilitation, as cross-language phonology in French and English is highly discrepant. Our data cannot test this possibility; however, similar reading studies in other languages like Dutch and English could play a critical role in evaluating this possibility.

In summary, the present findings suggest that bilingual language processing is language nonselective at early stages of comprehension regardless of contextual constraint. However, cross-language ambiguity may be rapidly resolved at later stages of comprehension for contexts that provide a high semantic constraint for a target word. These results argue for an integrated and context-sensitive bilingual language-processing system where the semantic framework that is constructed during reading provides important top-down influences on lexical access of words that are cross-linguistically ambiguous. Further investigation of the effects of lexical expectation on nonselective access will be important to our understanding of the bilingual mental lexicon and to the development of bilingual processing models, such as BIA+.

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Received January 29, 2008
Revision received August 1, 2008
Accepted August 9, 2008 ■