

# Bilinguals Show Weaker Lexical Access During Spoken Sentence Comprehension

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**Abstract** When bilinguals process written language, they show delays in accessing lexical items relative to monolinguals. The present study investigated whether this effect extended to spoken language comprehension, examining the processing of sentences with either low or high semantic constraint in both first and second languages. English-German bilinguals, German-English bilinguals and English monolinguals listened for target words in spoken English sentences while their eye-movements were recorded. Bilinguals' eye-movements reflected weaker lexical access relative to monolinguals; furthermore, the effect of semantic constraint differed across first versus second language processing. Specifically, English-native bilinguals showed fewer overall looks to target items, regardless of sentence constraint; German-native bilinguals activated target items more slowly and maintained target activation over a longer period of time in the low-constraint condition compared with monolinguals. No eye movements to cross-linguistic competitors were observed, suggesting that these lexical access disadvantages were present during bilingual spoken sentence comprehension even in the absence of overt interlingual competition.

**Keywords** Lexical access · Bilingualism · Sentence processing · Language comprehension · Eye-tracking

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When processing written language, bilinguals often show disadvantages in word recognition. For instance, compared to monolinguals, bilinguals show longer gaze-durations to target items when reading sentences (Gollan et al. 2011), slower RTs than monolinguals in lexical decision tasks (Duyck et al. 2008; Gollan et al. 2011), and slower N2 and N400 responses when judging target word length (Martin et al. 2011). Slower lexical processing has also been observed during language production for bilinguals (Gollan et al. 2011; Ivanova and Costa 2008; Kohnert et al. 1998). While a number of studies have examined the challenges non-native speakers face in speech perception (for a recent review, see Garcia Lecumberri et al. 2010), little research has explored disadvantages specifically within lexical access. The present experiment examines whether bilinguals' difficulty in target word processing during visual word recognition is also present during spoken sentence comprehension in both their first and second languages.

Previous work has suggested that bilinguals' difficulties in accessing target lexical items could potentially be due to cross-linguistic interference. When bilinguals perform a task in one of their languages, they simultaneously access information from their other language as well, and this *parallel language activation* has been observed across highly diverse language pairs in auditory processing (e.g., Blumenfeld and Marian 2007; Ju and Luce 2004; Marian and Spivey 2003a,b; Weber and Cutler 2004). By constantly co-activating both lexicons during comprehension, bilinguals are obligated to manage lexical competition from a greater number of potential candidates, and this increased competition from non-target lexical items may result in slower and/or weaker access to a given target lexical item. Therefore, one goal of the current study was to determine whether cross-linguistic competition is necessary to observe the bilingual disadvantage in lexical access, or whether lexical access difficulties can be found in the absence of overt interlingual competition.

The cross-linguistic interference account of lexical access difficulties in bilinguals would suggest that when cross-linguistic competition is reduced, bilinguals should not show any disadvantage in lexical access. Attenuating this competition can be accomplished by providing predictive sentence contexts, which has been shown to reduce (or even eliminate) language co-activation in both written (Duyck et al. 2007; Libben and Titone 2009; Schwartz and Kroll 2006) and spoken language processing (Chambers and Cooke 2009; Lagrou et al. 2013a,b). For example, Chambers and Cooke (2009) found that English-French bilinguals listening to sentences in their L2 French showed a marked reduction in looks to interlingual competitors if the sentence context preceding the target (e.g., *poule* [chicken]) was incompatible with the English competitor (e.g., *pool*). Participants were less likely to look at the competitor (*pool*) when they heard *Marie va nourrir ...* [Marie will feed ...], than when the sentence context was compatible with the competitor (e.g., *Marie va décrire ...* [Marie will describe ...]). Consistent results have been found for Dutch-English bilinguals, where sentence constraint reduced but did not eliminate the effect of interlingual homophones on target lexical decision times (Lagrou et al. 2011). In fact, sentence context, even when not predictive of the target, can result in decreased activation of cross-language competitors (Chambers and Cooke 2009; Titone et al. 2011).

The current study utilized this effect of sentence constraint to determine whether the bilingual lexical access disadvantage found in reading could be observed in spoken sentence comprehension (as indexed by processing of target items) when cross-language competition is attenuated (as indexed by the processing of competitor items). Using eye-tracking and the Visual World Paradigm, the present study measured lexical activation of target and competitor items presented in spoken English sentences for bilinguals listening in either their L1 (English-German bilinguals) or their L2 (German-English bilinguals). Our primary focus was on whether bilinguals showed reduced or weaker access to lexical items, relative to

monolinguals, and whether this difference was mediated by degree of lexical competition. In order to determine whether bilinguals' lexical access was affected by overt interlingual competition, each target item was presented with a cross-linguistic phonological competitor. Furthermore, the degree to which cross-linguistic competition was expected in each trial was manipulated by presenting the target word in a sentence that either provided predictive cues to the target word (thereby limiting the effect of cross-language competition), or did not provide predictive cues. By focusing on target activation as it is influenced by competitor activation, we aim to provide a direct measure of the speed and strength of lexical access in bilinguals.

Comparing L1 and L2 listeners allows us to address a second issue: how effects of sentence context on spoken word perception are modulated by language of presentation. Previous work in visual word recognition has suggested that bilinguals utilize sentence constraint differently in L1 versus L2 processing. Libben and Titone (2009) found that bilinguals reading sentences in their L2 showed evidence of interlingual homograph competition in early-stage measures (e.g., first fixation) for both high and low constraint sentences, but showed evidence of competition in late-stage measures (e.g., total reading time) only for low constraint sentences. Using the same set of stimuli, Titone et al. (2011) found that bilinguals reading sentences in their L1 did not show any early-stage effects of interlingual homographs; these readers showed late-stage effects independent of sentence context. The current study allows us to examine whether there are similar modulations of sentence constraint effects in spoken word recognition.

## Method

### Participants

All participants were recruited from the general community through the use of posted advertisements, and the sample of participants contained both undergraduate students, and community members from the surrounding area. Thirty German-English bilinguals participated in the study. Fifteen bilinguals had German as their native language (10 females), and fifteen had English as their native language (7 females). In addition, a control group consisting of fifteen English monolinguals (10 females) was tested. All bilinguals rated their L2-proficiency (understanding spoken language) to be at least a 6 on a scale from 0 (no proficiency) to 10 (perfect), and had been immersed in an L2-environment for at least four months. Both of our bilingual groups were late, sequential L2 learners, with initial ages of acquisition of 13.2 years ( $SD = 4.9$ ) for English-native bilinguals, and 10.2 years ( $SD = 2.3$ ) for German-native bilinguals,  $t(28) = -2.1$ ,  $p < .05$ . Additionally, the German-native bilinguals' average age at immigration to the United States was 26.6 years ( $SD = 4.19$ ), indicating that they began learning their second language prior to immigrating to an English speaking country. To investigate the context of L2 acquisition for our bilingual groups, the degree to which certain language-contexts contributed to their learning on a scale of 0 (not a contributor) to 10 (Most Important Contributor) was obtained from a language-background questionnaire (LEAP-Q, Marian et al. 2007). For both bilingual groups, the highest contributor to learning their native language (L1) was *Interacting with Family Members* (German-English = 9.2,  $SD = 1.33$ ; English-German = 9.5,  $SD = 1.13$ ), suggesting that they learned their L1 at home with family. In contrast, both bilingual groups rated *Interacting with Friends* as the highest contributor to L2 learning (German-English = 7.9,  $SD = 1.66$ ; English-German = 7.8,  $SD = 2.9$ ), and provided much lower ratings for *Interacting with Family* (German-English = 2.6,  $SD = 3.7$ ;

**Table 1** Linguistic background of English-native and German-native bilinguals

	English-native M (SD)	German-native M (SD)	Between-group statistics
Age	27.2 (7.1)	33.3 (6.1)	$t(28) = 2.5, p < .05$
Years of Education	19.7 (3.8)	18.1 (2.7)	$t(28) = 1.4, p > .1$
Age of initial L2-learning	13.2 (4.9)	10.2 (2.3)	$t(28) = -2.1, p < .05$
Age of attained L2-fluency	18.6 (6.0)	19.3 (5.0)	$t(28) = 0.4, p > .5$
Years in an English-speaking country	23.4 (6.4)	6.8 (8.5)	$t(28) = -6.0, p < .01$
Years in a German-speaking country	3.7 (6.9)	26.0 (4.6)	$t(28) = 10.4, p < .01$
Proficiency understanding English <sup>a,b</sup>	9.7 (0.6)	8.5 (0.8)	$t(28) = -4.5, p < .01$
Proficiency understanding German <sup>a</sup>	8.1 (1.0)	9.8 (0.4)	$t(28) = 6.0, p < .01$
Current percentage English exposure <sup>c</sup>	83.5 (12.3)	73.9 (19.6)	$t(28) = -1.6, p > .1$
Current percentage German exposure <sup>c</sup>	14.0 (12.3)	23.8 (20.1)	$t(28) = 1.6, p > .1$

<sup>a</sup> As rated by participants on a scale from 0 (no proficiency) to 10 (perfect)

<sup>b</sup> English monolinguals did not differ from English-native bilinguals in self-reported proficiency understanding English,  $M = 9.6, SD = 0.5$ . English monolinguals were not proficient in another language and had never studied a Germanic language other than English

<sup>c</sup> The percentages of current exposure do not sum to 100 % because several of our participants reported small percentages of current usage (2.5 % for English-native bilinguals ( $N = 7$ ), and 2.3 % ( $N = 12$ ) for German-native bilinguals) of a third language

English-German = 4.5,  $SD = 4.7$ ). The increased importance of interacting with friends for learning L2, combined with the later age of initial acquisition, suggests that the bilinguals likely learned their L2 as teenagers, in a school environment with their peers.

See Table 1 for a comparison of the language backgrounds of the two bilingual groups.

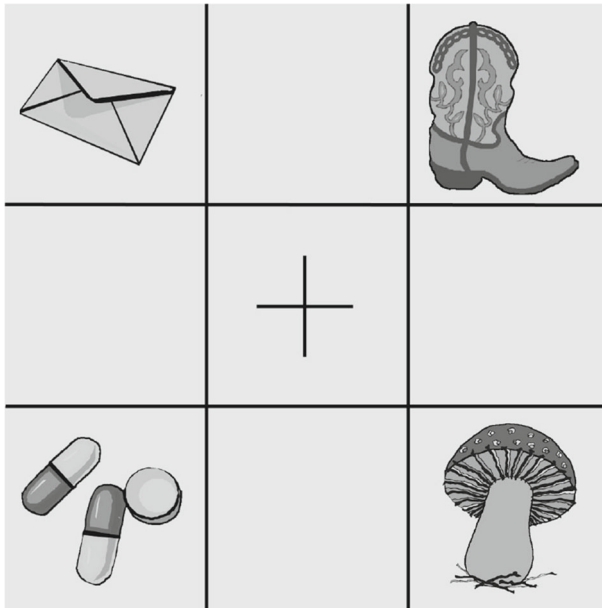
We assessed the L2-proficiency status of bilinguals using both self-reported (*LEAP-Q*) and standardized (*Peabody Picture Vocabulary Test, PPVT, Dunn and Dunn 1997*) measures. Results revealed that for all bilinguals the native language was their dominant language (see Table 1). Repeated-measures ANOVA revealed a significant effect of group on English PPVT scores  $F(2, 39) = 5.860, p < 0.01$ . Follow-up analyses revealed that German-native bilinguals ( $M = 183.9, SD = 11.5$ ) scored significantly lower than English-native bilinguals ( $M = 195.4, SD = 5.28$ ),  $p < .01$ , on the English PPVT, but neither group was significantly different from the English monolingual group ( $M = 189.1, SD = 9.63$ ; both  $ps > 0.1$ ). These results suggest that the two bilingual groups' receptive English vocabulary was similar to that of the English monolinguals.<sup>1</sup> Both bilingual groups also completed a version of the PPVT that had been translated into German; results revealed that German-native bilinguals ( $M = 198.5, SD = 3.0$ ) outperformed English-native bilinguals ( $M = 182.8, SD = 11.0$ ),  $t(28) = 5.3, p < .01$  on the German PPVT.

## Materials

### *Stimulus Pictures*

There were two types of stimulus displays. Displays in experimental trials (see Fig. 1) consisted of a central fixation cross and four pictures depicting the target word, a German

<sup>1</sup> PPVT data were not available for 3 of the 15 English monolinguals; thus, the ANOVA included 15 English-German bilinguals, 15 German-English bilinguals, and 12 English monolinguals.



**Fig. 1** Sample stimulus panel with target *pills* and German competitor *Pilz* (mushroom)

competitor, and two unrelated fillers. The position of each picture type was counterbalanced across trials. Displays in filler trials were identical to target displays, except they contained the target, three fillers, and no competitor. Pictures were obtained from Blumenfeld and Marian (2007) stimuli, Google image searches, or hand drawn. Pictures were black and white line-drawings with grey shadings.

### Stimulus Words

Forty English target words were selected,<sup>2</sup> and each target word was matched with a competitor. These were words that in English (*mushroom*) shared no word-initial phonological overlap with the target word (*pills*), but the German translation (mushroom—*Pilz*) overlapped phonologically with the English target. The mean amount of initial phonological overlap between the targets and competitors was 2.43 initial phonemes ( $SD = 0.8$ ) out of an average of 4.38 total phonemes (55.5%) for English target words and 5.18 total phonemes (46.9%) for German competitor words. The two fillers in each display were phonologically and semantically unrelated to both the target and competitor words in German and English. There was no semantic overlap between the four items in each display.

The SUBTLEX-US per-million (Brysbaert and New 2009) English target word frequency ( $M = 16.2$ ,  $SD = 25.5$ ) did not differ significantly from that of the German translation of

<sup>2</sup> Target words were evenly split between cognates (*pills*, German *Pilz*) and non-cognates (*pickle*, German *Essiggurke*). Additionally, cognate and non-cognate items were paired based on initial phonological overlap (i.e., cognate *pills* and non-cognate *pin*) to ensure that differences across cognate/non-cognate conditions were not due to differences in familiarity with specific phonemes. No effect of cognate status on any of our measures of interest was observed (all  $ps > 0.05$ ), potentially due to the overall lack of significant cross-language activation (see below) and consistent with previous findings by Gollan et al. (2011). Therefore, the cognate and non-cognate conditions were collapsed in the final analyses.

competitors ( $M = 18.2$ ,  $SD = 30.8$ ) obtained from SUBTLEX-DE (Brysbaert et al. 2011),  $t(78) = 0.31$ ,  $p > 0.5$ .

### *Stimulus Sentences*

Target words were embedded in English sentence contexts. Each target word appeared in two English sentences—one high-constraint and one low-constraint. Here, constraint refers to the degree to which the sentence context predicted the identity of the target word. Sentence context was manipulated at four specific points; at each point, a word or phrase semantically related to the target word did or did not appear. High- and low-constraint sentences were syntactically parallel and equal in overall word and syllable length. The target word always appeared in sentence final position and was preceded by the sequence “and [*determiner*]”. Below is an example of (A) a High-Constraint sentence and (B) a Low-Constraint sentence with the target word “can.”

- (A) High constraint: The drinker went to the recycling bin and threw away a bottle and a can.  
 (B) Low constraint: The typist went to the new conference room and brought along a printer and a can.

The effectiveness of the constraint manipulation was verified in a separate cloze norming experiment. Twelve English monolinguals completed the target sentences from which the target words had been removed. Participants inserted the correct target word significantly more often in the high-constraint sentences ( $M = 59\%$ ,  $SD = 6$ ) than in the low-constraint sentences (there were no instances of correct sentence completions;  $t(11) = 33.9$ ,  $p < .01$ ). These production probabilities are similar to those found in sentence completion tasks in previous bilingual sentence processing studies (e.g., Schwartz and Kroll 2006; Hell and Groot 2008).

Target sentences were recorded at 22.05 kHz, 16 bits by a monolingual speaker of American English. Target words were embedded in a control sentence frame and recorded separately. All recordings were amplitude-normalized. Experimental tokens were created by cross-splicing the target noun-phrase (including the determiner) from the neutral sentence frame into both the high- and low-constraint sentences. Research has shown that listeners are sensitive to fine phonetic detail when processing spoken sentences (e.g., Cho et al. 2007). By cross-splicing identical tokens of the target words into the experimental sentences, we were able to ensure that any differences in looks to the targets in the two sentence conditions were not due to acoustic differences between the target items across contexts.

To ensure that participants paid attention to the entire sentence context (and not simply the last word), we included 12 comprehension questions on filler trials, that required the participants to identify the subject, the location, or one of the two objects of the sentences. Participants answered the vast majority of the questions correctly ( $M = 94.3\%$ ,  $SD = 6.8$ ), suggesting that they did indeed pay attention to the entire sentence context and not just the target words. There was no difference in performance across participant groups ( $F(2, 42) = 1.25$ ,  $p > .05$ ).

The experiment consisted of a total of eighty target trials (40 targets, each in a high- and a low-constraint context). Target trials were intermixed with eighty filler trials. Trials were presented in blocks of 40 and were in pseudo-random order with no more than two target trials in a row. High- and low-constraint sentences containing the same target word did not appear in the same block.

## Procedure

After giving informed consent and filling out the LEAP-Q, participants performed the eye-tracking task. An ISCAN eye-tracker was used to track participants' gaze. Sound files and associated picture displays were presented to participants using Superlab. The name of the target picture was presented 200 milliseconds after the appearance of the picture display, i.e., the picture display appeared concurrently with the onset of the "and[determiner] [target word]" phrase. This short preview time may also serve to reduce the activation of cross-language neighbors; using this display onset timing, [Huettig and McQueen \(2007\)](#) failed to observe effects of phonological competitors during spoken word perception.

Participants were instructed to identify the target word. They were familiarized with the task during eight practice trials on neutral stimuli that did not appear in the experimental session. The eye-tracking experiment lasted approximately 30 minutes. Afterwards, all participants completed the CTOPP memory-for-digits task and the English PPVT. Bilinguals, in addition, completed the German PPVT and were asked to name in German the pictures of all competitors from the experiment. This was done to ensure that participants were generally familiar with the German translations of the competitors. German-native bilinguals recognized 89.5% of the 40 competitor pictures ( $M = 35.8$ ,  $SD = 2.5$ ), whereas English-native bilinguals named 64.8% of the pictures correctly ( $M = 25.9$ ,  $SD = 6.7$ ).

All participants were tested by a native German-English bilingual, and all interactions between the participants and the experimenter were in English (except for the German PPVT, which was administered in German *after* the eye-tracking portion of the experiment). The eye-tracking experiment was performed in English only.

## Coding and Analysis

The eye-tracking data, which consisted of video output of participants' field of view with superimposed fixation cross-hairs, were hand-coded at a temporal resolution of 33.3 ms per frame. The data were analysed using growth-curve analysis (GCA), a statistical method for modelling variations across time in data such as those collected through eye-tracking ([Magnuson et al. 2007](#); [Mirman et al. 2008](#)). The eye-tracking analyses were restricted to items that bilinguals labeled correctly in the naming task.

## Error Rate

Trials with erroneous target selections and their constraint-matched trials were excluded from all analyses. The overall error rate was very low (0.7% of  $N = 3600$  trials across groups). Monolinguals made no errors ( $N = 1,200$  trials). German-native bilinguals were significantly less accurate (1.8% errors; Fisher's exact test,  $p < .05$ ). English-native bilinguals were also less accurate than monolinguals (0.4% errors, with this difference trending towards significance;  $p < .07$ ).

For German-native bilinguals, the majority of the errors (16/21) were incorrect selections of the competitor picture. Some of the English-native bilinguals' errors also resulted in errors of competitors versus fillers (2/5 errors were competitor selections). Since 15 of the 26 erroneous trials involved the target-competitor pair *pulley-Pulli* (*sweater*), we excluded these trials and their matched trials for all participants. Altogether, 4.6% of trials were excluded from further analyses due to error in the experimental task.

## Results

### Analyses of Competitor Looks

In order to examine whether the monolingual, German-English bilingual, and English-German bilingual groups activated the competing item during processing, GCAs were performed. The effect of time on fixations was modeled with orthogonal polynomials (Mirman et al. 2008). To capture how experimental conditions and participant groups modulated changes to fixations over time, the model included interactions of the polynomials with fixed effects of Group (English monolingual, German-English bilingual, and English-German bilingual), Condition (Competitor, Unrelated Distractor), and Sentence Constraint (High, Low), along with their interactions. Random intercepts and slopes for the orthogonal polynomials representing changes over time were included for participants and the nested effects of participant by within-participant factors (Condition and Constraint). All factors were treatment coded. Because the primary interaction of interest in these analyses was between Group and Condition (we expected that cross-linguistic activation should be found only in the bilingual groups and should involve differences between fixations to competing items and distractor items), for ease of presentation, we only report results which include significant Group  $\times$  Condition interactions. To determine the appropriate window of analyses, we selected the point at which participants had identified the target item, operationally defined as the last time point at which target looks peaked across all groups and conditions. All analyses were therefore conducted in the time window between 0 ms (target word onset) and 1,033 ms post-onset of the target image. To determine the significance of fixed effects, the  $t$  values of the corresponding coefficients was assumed to approximate a  $z$  distribution.

#### *English-German Bilinguals Versus Monolinguals*

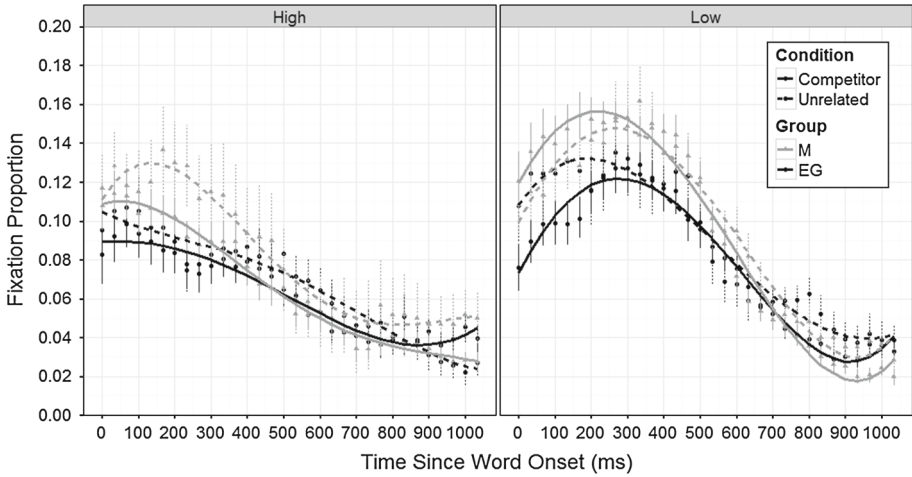
Although significant Group  $\times$  Condition interactions were found for the Monolingual and English-German bilingual comparisons, these were limited to the quadratic term.<sup>3</sup> This effect is not likely to be very meaningful due to the small mean fixation proportions (between approximately 0.08 and 0.11) and the fact that the peakedness (which is measured by the quadratic term) of the curves is heavily influenced by fixation proportions at target onset. More specifically, bilinguals' competitor fixations started at a lower proportion, but converged with the unrelated distractor fixations after approximately 250 ms. Thus, the difference in peakedness may simply reflect the bilinguals' competitor fixations "catching up" to that of the unrelated distractors that were being preferentially (but, importantly, non-significantly) fixated at target onset. Overall, this pattern of results suggests that competitors were not strongly activated for English-German bilinguals (Fig. 2).

#### *German-English Bilinguals Versus Monolinguals*

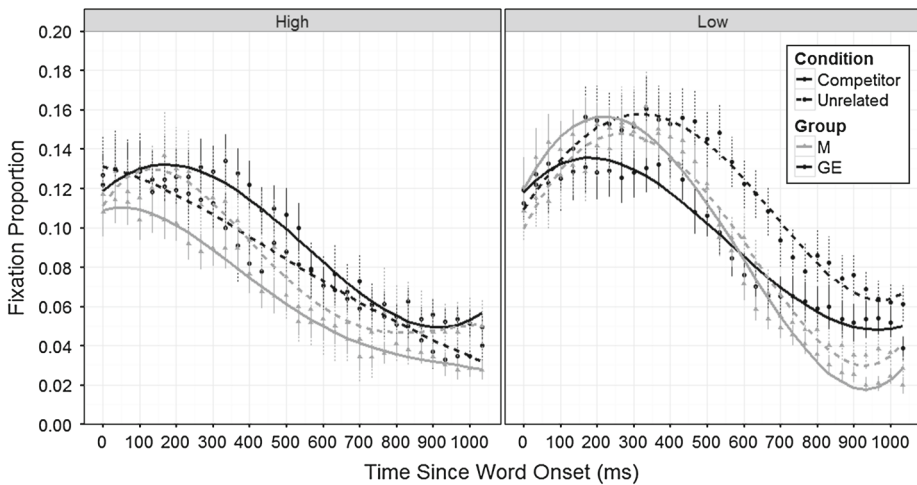
The GCA revealed no significant Group  $\times$  Condition interactions. There was a significant effect of Condition on the linear term ( $Est. = -0.131, SE = 0.05, p < 0.01$ ), indicating that both groups were slower to terminate fixations to the unrelated distractor items relative to competitor items (Fig. 3). Critically, however, there was no significant interaction, suggesting that competitor activation was minimized for German-English bilinguals.

<sup>3</sup> A significant three-way Group  $\times$  Condition  $\times$  Constraint interaction was found at the quadratic term ( $Est. = 0.162, SE = 0.075, p < 0.05$ ). Analyses within condition showed a significant Group  $\times$  Condition interaction was limited to the Low Constraint condition ( $Est. = -0.121, SE = 0.054, p < 0.05$ ).





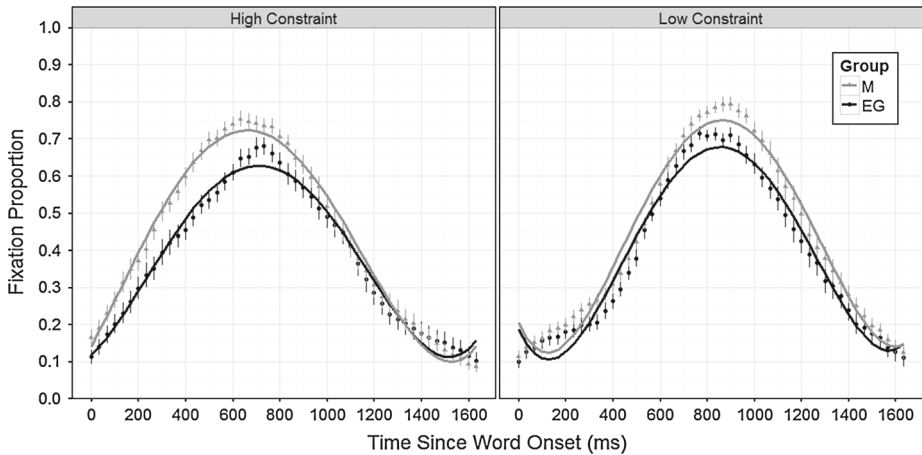
**Fig. 2** Model fit data for Monolingual (M) and English-German bilingual (EG) participants' looks to competitor (solid lines) and unrelated distractor (dashed lines) items for the High and Low Constraint conditions. Error bars represent one standard error



**Fig. 3** Model fit data for Monolingual (M) and German-English bilingual (GE) participants' looks to competitor (solid lines) and unrelated distractor (dashed lines) items for the High and Low Constraint conditions. Error bars represent one standard error

### Analyses of Target Looks

A GCA, similar in structure to those above (excluding the factor distinguishing competitors and fillers), was performed. To determine the time-window for target analyses, we selected the point at which non-target items (unrelated or competing distractors) were no longer considered viable candidates for selection, operationally defined as the latest time point at which the proportion of distractor or competitor looks was above 5%. As a result, all target analyses were performed on the time-window from 0 ms (onset of the target word) to 1,663 ms.



**Fig. 4** Model fit data for Monolingual (M) and English-German bilingual (EG) participants' looks to target items in the High and Low Constraint conditions. *Error bars* represent one standard error

#### *English-German Bilinguals Versus Monolinguals*

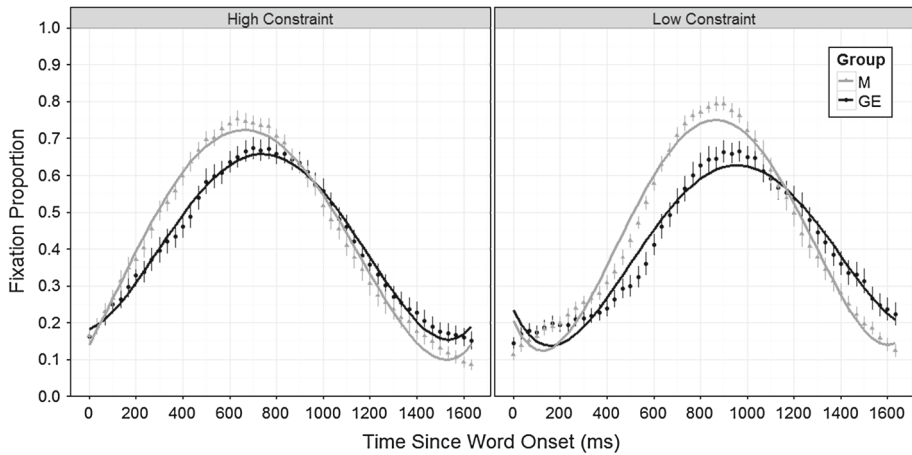
Growth-curve analysis revealed that English-German bilinguals looked less overall at targets than monolinguals (Intercept: *Est.* =  $-0.046$ , *SE* =  $0.022$ ,  $p < 0.05$ ). A significant two-way interaction between Constraint and Group at the linear term (*Est.* =  $0.443$ , *SE* =  $0.166$ ,  $p < 0.01$ ) appeared to be driven by differences in the magnitude of the Constraint effect across Groups. Specifically, in the overall analyses, the main effect of Constraint on the linear term was weaker for English-German bilinguals (*Est.* =  $-0.438$ , *SE* =  $0.091$ ,  $p < 0.001$ ) relative to monolinguals (*Est.* =  $-0.881$ , *SE* =  $0.139$ ,  $p < 0.001$ ). Though both groups looked at targets more quickly in the High Constraint condition, the effect was larger in the monolinguals. While the two groups did not differ in target fixations for either the Low Constraint or High Constraint condition (all  $ps > 0.05$ ), there was a trend toward a group difference in the High Constraint condition (Fig. 4).

#### *German-English Bilinguals Versus Monolinguals*

Significant Group  $\times$  Constraint interactions were found at the quadratic (*Est.* =  $-0.334$ , *SE* =  $0.14$ ,  $p < 0.05$ ) and quartic terms (*Est.* =  $0.203$ , *SE* =  $0.101$ ,  $p < 0.05$ ). Follow-up analyses indicate that the German-English bilinguals recognized the target items more slowly than monolinguals (as indicated by the shallowness of the curves; see Fig. 5) in the Low Constraint condition only (quadratic: *Est.* =  $0.564$ , *SE* =  $0.145$ ,  $p < 0.001$ ). In addition, German-English bilinguals appeared to maintain activation of the target later in processing relative to monolinguals (quartic: *Est.* =  $-0.206$ , *SE* =  $0.094$ ,  $p < 0.05$ ). The groups did not differ in the High Constraint condition ( $ps > 0.05$ ).

## **Discussion**

In the present study, we examined whether bilinguals have difficulties in lexical access during spoken language processing and, if so, whether such difficulties arise solely due to cross-



**Fig. 5** Model fit data for Monolingual (M) and German-English bilingual (GE) participants' looks to target items in the High and Low Constraint conditions. *Error bars* represent one standard error

linguistic competition. Results revealed that both bilingual groups differed in their pattern of looks to targets compared to the monolingual group, but did not differ in their pattern of looks to competitors. Furthermore, the extent to which bilinguals had difficulty accessing the target lexical items was mediated by sentence context and was modulated by whether the task was presented in the bilinguals' L1 or L2 English. English-German bilinguals showed fewer overall looks to target items than monolinguals in both the High- and Low-Constraint conditions, and trended toward accessing the targets more slowly than monolinguals in the High Constraint condition, suggesting that the English-German bilinguals were unaffected by the predictable sentence context. The German-English bilinguals, in contrast, showed slower target recognition relative to monolinguals and maintained target activation over a longer period of time than the monolinguals, but only when sentence constraint was low. These results suggest that even when no overt cross-linguistic competition is observed behaviorally, lexical access is weaker in bilinguals relative to monolinguals.

In addition, these results highlight how the usefulness of sentence context for aiding lexical access may depend upon whether the bilingual is listening to sentences in her native language or her non-native language. Specifically, sentence constraint appeared to influence lexical access in bilinguals listening in their L2 (German-English), but not those performing the task in their L1 (English-German). Previous work exploring bilingual language co-activation in sentence contexts may help explain these findings. For instance, [Libben and Titone \(2009\)](#) observed late-stage interference effects for L2 readers in low constraint sentences, but not in high constraint sentences. This finding closely resembles the pattern seen in our German-English bilinguals, where lexical access difficulties were found only in the low constraint condition, and suggests that L2-exposed bilinguals may utilize the predictive context found in high constraint sentences to manage interference and bolster lexical processing. In contrast to the L2 readers, [Titone et al. \(2011\)](#) found that bilinguals reading in their L1 showed late-stage interference effects that were independent of sentence context. Again, this pattern closely resembles our finding that the English-German bilinguals, who performed the task in their L1, showed evidence of lexical access difficulties that were independent of sentence constraint. The English-German bilinguals, then, appeared not to rely on sentence-level contextual cues when processing the target words in the current study.

Research on speech-in-noise processing provides additional evidence that native and non-native listeners use context differently when processing language. Bradlow and Alexander (2007) found that native English speakers listening to speech in noise benefitted from both the use of clear speech and highly-predictable sentence context independently—in contrast, non-native speakers required *both* clear speech and predictable context to understand the signal. This is consistent with the claim that non-native listeners (e.g., our German-English bilinguals) rely more on the contextual information carried by the sentence than native speakers (e.g., our English-German bilinguals).

Though the pattern of results seen in our two bilingual groups was influenced by sentence constraint and language of presentation, both showed evidence of lexical access difficulties when compared to monolinguals in the absence of overt phonological competition. This result indicates that cross-linguistic competition alone is likely not sufficient to explain the lexical access difficulties found in bilinguals during auditory comprehension. Below, we consider three alternative accounts of these difficulties.

Bilinguals' difficulties in lexical access could reflect differences in perceptual processing. Bilinguals' phonological systems interact and influence one another, from both L1 to L2 (e.g., Flege 1995; Flege et al. 1997; Navarra et al. 2005) and L2 to L1 (see Pavlenko 2000 for a review). As a result, bilinguals' underlying phonemic representations may differ from monolinguals' (e.g., by the number of available categories or the rigidity of boundaries between categories). Therefore, it is possible that our bilinguals perceived the English phonemes in the experiment as poorer exemplars of their phonetic categories, which could ultimately lead to phonological information being a weaker cue to lexical identity for bilinguals relative to monolinguals.

Another alternative account attributes the disadvantage in lexical access experienced by bilinguals to a type of fan effect (Anderson 1974). Because bilinguals know two languages, they activate a larger set of cohort candidates as speech unfolds. Perhaps the resources available for bilinguals to activate lexical items were spread among a larger number of cohort candidates (i.e., overlapping items in both languages). This could have resulted in decreased activation of the target, along with insufficient activation for any non-target cohort item, which may explain the observed lack of competition. Consistent with this, there is evidence that high cohort density can negatively impact word processing, and that cohort density effects do not require the presence of direct competition within the task. For instance, Magnuson et al. (2007) found that participants fixate high cohort density targets less often and later than low cohort density targets.

Finally, the observed bilingual disadvantage in lexical access during spoken sentence comprehension is also consistent with the frequency-lag hypothesis. Gollan et al. (2011; see also Gollan et al. 2008) observed that disadvantages in target-word reading times were strongly modulated by lexical frequency. The authors suggest that because bilinguals only use one language at any given moment, individual lexical items from both of their languages are used (and accessed) less often than in monolinguals of either language, resulting in a "frequency lag." In other words, monolinguals' lexical representations are more easily accessed relative to bilinguals', because bilinguals' decreased experience using individual lexical forms in either language results in weaker links between word form and meaning. Further research would benefit from a direct test of the predictions of these alternative accounts of lexical access difficulties in spoken word comprehension.

It is important to note that while overt cross-linguistic competition was not observed during bilingual spoken sentence comprehension in this particular experimental context, under many other circumstances overt competition does occur, providing strong support for the co-activation of the non-target language during speech perception (e.g., Blumenfeld and

Marian 2011; Ju and Luce 2004; Marian and Spivey 2003a,b; Weber and Cutler 2004). Further research is required to understand how cross-linguistic competition effects influence lexical access in bilinguals during sentence comprehension.

In summary, the current study found a lexical access disadvantage during bilingual comprehension of spoken sentences in L1 and L2, and suggests that this disadvantage is mediated by both sentence constraint and language of presentation (L1 or L2). Further research is clearly required to understand the role of various mechanisms underlying bilingual spoken language processing. Indeed, as bilinguals attempt to access the lexical forms of words they hear, there may be multiple mechanisms at play, among them interference, frequency of use, and/or perceptual processing difficulties. By exploring lexical access in bilinguals, the present work contributes to our understanding of how experience with more than one language can affect spoken language comprehension.

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