Language bias and proficiency effects on cross-language activation

A comprehension and production comparison

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Recent research proposes that language bias and proficiency modulate cross-language activation in comprehension and production, but it is unclear how they operate and whether they interact. This study investigates whether stress differences between Spanish-English cognates (*material*, final-syllable stress in Spanish) affect how native-English second-language-Spanish bilinguals recognize Spanish words (*materia* "subject/matter," second-syllable stress in Spanish). In a Spanish-English eye-tracking experiment (and parallel production task), participants heard/produced trisyllabic Spanish targets with second-syllable stress (*materia*) and saw four orthographic words, including the target and a Spanish-English cognate competitor. Cross-language activation was examined by manipulating the stress of the cognate in English. In comprehension, English cognates with the same stress as the Spanish target (*materia* vs *material*) were predicted to cause more cross-language interference than English cognates with a different stress (*litera* "bunk bed," vs *literal*), but the reverse pattern was expected in production. Participants were assigned to a Spanish-bias condition (20% of English (filler) items), or an English-bias condition (65% of English (filler) items). Results indicate that English cognates with the same stress as the Spanish target interfered with the recognition of the Spanish target only in the English-bias condition (but facilitated its production), while increasing Spanish proficiency helped reduce this cross-linguistic interference.

Keywords: bilingualism, comprehension, production, stress, mode

1. Introduction

During word recognition, lexical candidates that closely match the input become partially activated and compete with the target word for recognition (e.g.,

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Desroches, Newman, & Joanisse, 2009; Luce & Pisoni, 1998; Marlen-Wilson, 1987; McClelland & Elman, 1986; Seidenberg, Tanenhaus, Leiman, & Bienkowski, 1982). For example, words such as *carpool* and *carton* would compete for selection when hearing the target word *carpet*. Significantly, recent research has shown that bilinguals, including simultaneous bilinguals and early and late second language (L2) learners, activate words in both of their languages even when they consciously intend to use only one language (e.g., Blumenfeld & Marian, 2011; Canseco-Gonzalez et al., 2010; Desmet & Duyck, 2007; Dijkstra, 2005; Marian & Spivey, 2003a, 2003b; Schulpen, Dijkstra, Schriefers, & Hasper, 2003; Weber & Cutler, 2004). So, for bilinguals, as a spoken word in the speech signal unfolds, not only lexical candidates that most closely match the input in the intended language, but also words in the unintended language, become partially activated and compete for recognition. Successful recognition of the speech signal, thus, involves inhibiting not only the non-intended word, but also the non-intended language, and they do so not only in language comprehension, but also during language production (e.g., Costa & Santesteban, 2004; Costa, Santesteban, & Ivanova, 2006; Grainger & Beauvillain, 1987; Jackson, Swainson, Cunnington, & Jackson, 2001; Meuter & Allport, 1999).

Individuals who know two or more languages, then, need to engage in greater cognitive "gymnastics" than monolinguals, as they not only need to balance within-language competition, but also cross-language activation. Unclear, however, is how cross-language activation takes place and what factors modulate it, although several factors such as language dominance or language bias have been proposed to explain how bilinguals balance their two languages (e.g., Grosjean, 1998; Guo & Peng, 2006; Ju & Luce, 2004; Marian & Spivey, 2003a; Soares & Grosjean, 1984; Spivey & Marian, 1999; Weber & Cutler, 2004).

The literature has proposed different ways of understanding language dominance, such as whether the unintended language is the native language (L1) or the L2, whether or not the unintended language is used more often than the intended language, and how proficient bilinguals are in both languages. For example, more cross-language activation has been reported when the unintended language is the L1 and bilinguals are performing the task at hand in their L2 than in the reverse scenario (e.g., Ju & Luce, 2004; Spivey & Marian, 1999; Weber & Cutler, 2004). Prolonged use of the less dominant language (e.g., in a recent L2 immersion), however, may overcome the stronger activation from the L1 (e.g., Duffau, 2008; García-Pentón, Pérez Fernández, Iturria-Medina, Gillon-Dowens, & Carreiras, 2014; Martino, Brogna, Robles, Vergani, & Duffau, 2010; Mohades et al., 2012). Finally, bilinguals activate more phonologically overlapping words from the unintended language more with increasing proficiency in that language (e.g., Chee, Tan, & Thiel, 1999; Golestani et al., 2006; Guo & Peng, 2006; Jeong et al., 2007; Klein, Watkins, Zatorre, & Milner, 2006; Perani et al., 2003; Silverberg & Samuel, 2004; Weber & Cutler, 2004). It is common to find evidence of asymmetric switching changes associated with having to inhibit the dominant language while processing the less-dominant language (but not to the same degree in the opposite direction). However, higher L2 proficiency has led to smaller asymmetric switch costs (e.g., Meuter & Allport, 1999), speculated to even disappear for highly proficient bilinguals. That is, once the difference in proficiency between the two languages is minimal, the amount of inhibition applied to both languages is similar (see Monsell, Yeung, & Azuma, 2000).

Cross-language activation may also be modulated by factors that have been shown to affect language bias, including the interlocutor, the situation, the content of discourse, and the function of the interaction (e.g., Dijkstra & van Hell, 2003; Grosjean, 1998; Marian & Spivey, 2003a; Soares & Grosjean, 1984). For example, the degree of cross-language interference is smaller when bilinguals are in a monolingual setting.

What remains unclear from previous research, however, is how language (here, L2) proficiency and language bias modulate bilinguals' activation of bilinguals' two language systems, whether the two factors interact (e.g., more proficient bilinguals could show less sensitivity to language bias as a result of better controlling for the degree of cross-language activation), and whether (and if so, how) the degree of involvement of these factors differ in language comprehension as opposed to language production. Experiments in which bilinguals are asked to work in both of their languages (i.e., in a bilingual language mode) may lead to more cross-language competition, but such an effect may depend in part on their L2 proficiency, and it may be stronger in language comprehension or language production, depending on the degree of control over cross-language activation that bilinguals can exert in these two types of tasks. The current study examines how differences in word-level stress placement between two languages (Spanish and English) affect the processing of cognate words in language tasks aimed to put bilinguals into different points in the bilingual language mode continuum (Grosjean, 1998).

Research has shown that in languages that have word-level stress, greater activation of words that match the signal both segmentally and suprasegmentally is observed (as compared to words that only match the signal segmentally) for both native speakers (e.g., Cooper, Cutler, & Wales, 2002; Soto-Faraco, Sebastián-Galles, & Cutler, 2001) and L2 learners (e.g., Martínez-García, Van Anne, Brown, R., & Tremblay, n.d.; Tremblay, 2008). However, it is unclear whether stress placement that differs between two languages can interfere with the recognition of cognate words. Interestingly, Spanish and English have a number of words that share the same (orthographic) segments (i.e., cognates) but do not have the same stress pattern (e.g., the word *material*, which has the same meaning in both languages, has second-syllable stress in English but final stress in Spanish). In this case, it is expected that the corresponding segmental make-up of the cognate words will make them highly activated in both languages. Bilingual listeners' ability to use stress to recognize Spanish words should thus be contingent on their ability to use Spanish stress to inhibit the English competitor.

This research examines the degree of lexical competition that cognates with similar vs. different stress patterns in Spanish and English create for English-Spanish bilinguals. It does so using the visual world eye-tracking paradigm and an adaptation of this paradigm in speech production. This study examines whether the presence of cognate competitors with interfering stress placement influences the recognition of Spanish words in a task where participants would expect to hear (Experiment 1) or produce (Experiment 2) more Spanish than English or more English than Spanish (language bias) by testing English-Spanish bilinguals. Both experiments also examine how L2 proficiency modulates cross-language activation in the task, contributing to a better understanding of how language proficiency and language bias modulate cross-language activation in perception and in production.

2. Experiment 1: Comprehension

2.1 Participants

A total of 40 English-Spanish bilinguals (19 females; mean age: 26, standard deviation (SD): 5) participated in the study. Participants were native speakers of English with no significant exposure to Spanish or other languages before puberty (age of acquisition range: 9–21), with an intermediate-to-advance proficiency level in Spanish. None of the participants reported speech, hearing, or other language impairments. Some biographical information about these participants can be found in Table 1, together with their composite proficiency score, that was calculated by averaging the participants' percent accuracy on an multiple choice test (modified from Brown, 1980) and the LexTALE task (a lexical decision task) in Spanish.[1]

1. Originally, a group of Spanish-English bilinguals was also included to determine how bilingual activation may depend on whether the unintended language is the L1 or the L2 and how individual differences in L2 proficiency influenced the degree of cross-language interference for each group. However, since the two groups of participants tested were ultimately not comparable (the two groups differed in both their L2 proficiency scores and their L2 experience), and due to the length limitations, only the results of the English-Spanish bilinguals are reported.

Table 1. English-Spanish bilinguals' language background and proficiency information

	Age of first exposure to Spanish	Years of Spanish instruction	Number of months spent in an Spanish-speaking environment	Proficiency in Spanish (averaged score)
Mean	14.1	8.1	11	73.5%
SD	3.4	3.8	16.9	14.1%

Note. Mean (SD)

2.2 Materials

A total of 24 Spanish trisyllabic target-competitor word pairs with regular stress placement were selected for this experiment, 12 of which were heard in the stress-interference condition and 12 in the no-stress-interference condition. In the stress-interference condition, the cognate competitor (e.g., *material* as competitor for the target *materia*) showed a mismatch in stress placement between the English word and the Spanish word: While the competitor word has final stress in Spanish, it has the same stress pattern as the Spanish target word in English. On the other hand, in the no-stress-interference condition, the cognate competitor had a stress pattern in English that should not create any interference with the recognition of the Spanish target word. For example, both the Spanish and the English pronunciation of the cognate competitor *literal* differs in stress from the Spanish target (*literal* is stressed on the third syllable in Spanish but on the first syllable in English). Thus, competitor words in no-stress-interference condition are not expected to interfere as much with the recognition of the Spanish target word or listeners may in fact distinguish the target from the competitor words as early as in the first syllable (where both languages already differ with respect to stress pattern).

The log frequency of the target and competitor words was obtained using the subtitle token corpus in EsPal (Duchon, Perea, Sebastián, Martí, & Carreiras, 2013). Target words in the two stress conditions did not differ statistically in either frequency ($t(22) = 1.53$, $p > .05$) or length ($t(22) < |1|$). A comparison of the competitor words in the two stress conditions yielded the same pattern, with no significant difference in either frequency ($t(22) < |1|$) or length ($t(22) < |1|$). The visual display contained the target word, a competitor word, and two distracter words, all of which were trisyllabic. The distracter words did not overlap segmentally with the target or competitor words, but they overlapped segmentally with one another in their two first syllables (see Appendix A for the complete list of stimuli (target, competitor, and distracter words) used in Experiments 1 and 2).

The 24 critical trials were pseudo-randomized with 136 filler trials. The target, competitor, and distracter words in the filler trials were similar to those in the critical trials in log-transformed frequency and length. Half of the test items in the filler trials had a target word with final stress and the other half had a target word with penultimate stress in Spanish. In the filler trials, a Spanish-English cognate word was always the target word (half of them with final -CV syllable, as in *probable*, and the other half with -CVC final syllable, as in *maternal*), and it was heard either in Spanish or in English (as described in more detail in the next section).

The auditory stimuli (in English and Spanish) were recorded by a female native speaker of Castilian Spanish, to avoid including an extra cue to the language of the trial (e.g., the identity of the speaker). This speaker was judged by two native speakers of English (naïve to the purpose of the current investigation) as not having much of a foreign accent in English.

2.3 Procedure

The participants completed the experimental session in a quiet room. The eye-tracking experiment was compiled with Experiment Builder software (SR Research), and the participants' eye movements were recorded with head-mounted EyeLink II eye-tracker (SR Research). The signal from the eye tracker was sampled every four milliseconds. An ASIO-compatible sound card was used on the display computer to ensure that the audio timing would be accurate. The experiment began with a calibration of the eye tracker using the participants' right eye, or left eye of the right eye could not be tracked sufficiently well. This initial calibration was followed by a practice session (four trials) and by the main experiment (160 trials in four blocks of 34 trials). In each trial, participants first viewed the four orthographic words for 4,000 ms, which they were instructed to silently read. Orthographic words were included because the visual stimuli need not represent concrete objects, and this presentation has been found to be more sensitive to phonological manipulations than the traditional version using pictures (e.g., Huettig & McQueen, 2007; Weber, Melinger, & Lara Tapia, 2007). The words then disappeared, and a fixation cross appeared and stayed on the screen for 500 ms. As the fixation point disappeared and the same four words reappeared on the screen, participants heard the target word through headphones and clicked on the word that matched the acoustic input as quickly and accurately as they could. Participants' eye movements were measured from the onset of the target word. The trial ended with participants' response, with an inter-trial interval of 1,000 milliseconds. The eye tracker was calibrated at the beginning of each block and whenever it was necessary during the experiment. The participants completed the experiment in approximately 40 minutes. Figure 1 presents a visual representation of a trial in both conditions.

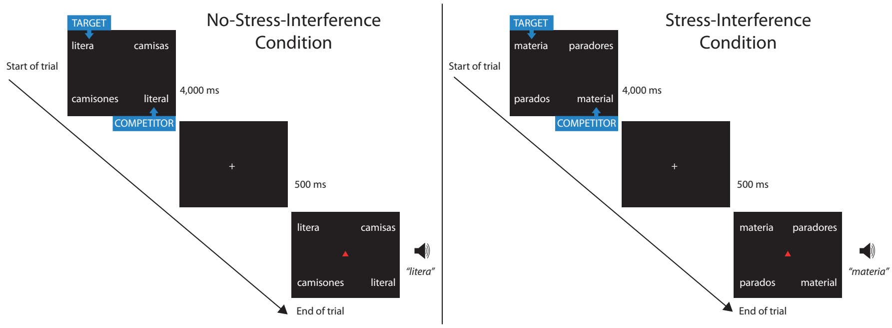

Figure 1. Visual example of two trials in Experiment 1 in the stress-interference and no-stress-interference conditions separately

The language bias was created by manipulating the language in which participants heard the target word (identical Spanish-English cognate) in the filler trials. Participants were quasi-randomly divided into two groups: one group completed a version of the experiment biasing participants towards expecting to hear more Spanish words (Spanish-bias group), whereas another group completed a version biasing them towards expecting to hear more English words (English-bias group). The two bias groups did not differ in L2 proficiency ($t(19) < |1|$) or in other individual differences measures (e.g., age of acquisition ($t(19) < |1|$), immersion in the L2 environment ($t(19) < |1|$), or years of instructions ($t(19) < |1|$)).

The test items were presented in four blocks (34 trials per block), the first block including only filler trials (to reinforce the bias towards one language or the other) and the other three containing four trials from each target condition. The order of the experimental and filler trials within block was randomized across participants, but not the order of blocks. Participants assigned to the Spanish-bias group heard 80% of the target words in Spanish and only 20% in English and participants assigned to the English-bias group 65% of the target words in English and the other 35% in Spanish (throughout the experiment and after controlling for other factors such as final syllable structure or stress placement of the target word). After the experiment, the L2 learners completed the multiple-choice test and the LexTALE in Spanish that served as measurement of their Spanish proficiency.

2.4 Data analysis

Proportions of fixations in each of the four regions of interest (corresponding to the four orthographic words) were analyzed from 0 to 1,500 ms, with a delay of 200 ms (it takes approximately 200 ms for listeners to program and launch an eye movement (Hallett, 1986)). Statistical analyses were conducted on the *difference* between target and competitor fixations (i.e., the proportion of competitor fixations was subtracted from the proportion of target fixations), as this dependent variable is a more sensitive measure of target-over-competitor-word activation.

Growth curve analysis (GCA) was used to model listeners' differential proportions of fixations (Mirman, Dixon, & Magnuson, 2008), which allows to model the curvilinear relationship between proportions of eye fixations over time. This statistical method allows modeling the shape of participants' overall fixation line rather than their average fixations at arbitrary points in time, as it could happen when doing time-window analysis being, then, less subjective. To conclude that stress of the competitor word (stress-interference or no-stress-interference), the language bias manipulation (English-bias or Spanish-bias) or participants' L2 proficiency had an effect on participants' fixations, the GCA outcome results must reveal *interactions* between these variables and at least one time polynomial (apart from showing a significant effect of these variables by themselves). Such interactions would be indicative that the shape of participants' fixation line differs between conditions, an effect that would reflect their intake of the speech signal.

The GCAs were run on participants' differential proportions of fixations using the *lme4* package in R (Bates, Mächler, Bolker, & Walker, 2015). The analysis included English stress (stress-interference vs. no-stress-interference, with the no-stress-interference as the baseline), Language bias (English-bias vs. Spanish-bias, with the Spanish-bias as the baseline), Proficiency (arcsine transformed and centered) as fixed effects, as well as all two- and three-way interactions. A backward-fitting function from the package *LMERConvenienceFunctions* (Tremblay & Ransijn, 2015) was used to identify the model that accounted for significantly more of the variance than all simpler models, as determined by log-likelihood ratio tests. *P*-values were calculated using the *lmerTest* package in R (Kuznetsova, Brockhoff, & Christensen, 2016) and only the results of the model with the best fit are reported. Analyses yielding significant interactions between English stress, language bias and/or proficiency were followed up by subsequent GCAs conducted on two bias groups separately, with the alpha level being adjusted to .025. All analyses included participant and item (i.e., target word) as random intercepts, and the time polynomials as random slopes for the participant variable, thus modeling a different line shape for each participant.

The predictions of the present study are the following: If English stress modulates lexical access in bilinguals' processing of Spanish stress, in addition to showing a significant effect of English stress (with greater differential proportions of fixations in the no-stress-interference than in the stress-interference conditions), listeners should show a significant interaction between English stress and the linear time polynomial (with a shallower slope in the stress-interference than in the no-stress-interference condition) and/or the quadratic time polynomial (with a more convex, i.e., U-shaped, fixation line in the stress-interference than in the no-stress-interference). A shallower slope and/or more convex fixation line in the stress-interference condition would be indicative of increased lexical competition taking place in that condition as a result of listeners' activation of the phonological stress patterns of that word in both English and Spanish. If English stress (stress-interference) interacts with language bias, in addition to a larger effect of English stress in the English-bias condition than in the Spanish-bias, listeners should show significant three-way interactions between English stress, language bias, and the linear time polynomial and/or the quadratic time polynomial, with the aforementioned two-way interactions between English stress and time being *stronger* in the English-bias than in the Spanish-bias condition.

2.5 Results

Figure 2 shows bilinguals' differential proportions of fixations in the stress-interference and no-stress-interference conditions in the Spanish-bias and English-bias conditions (see Appendix B for participants' separate proportions of target, competitor, and distracter fixations). More positive values on the graph indicate that participants looked more at the target than the competitor.

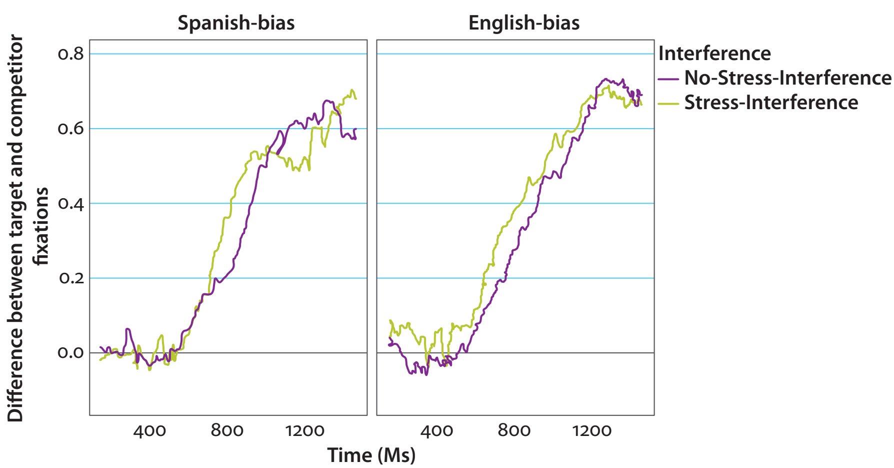

Figure 2. Bilinguals' differential proportions of fixations in the stress-interference and no-stress-interference conditions separately for the Spanish-bias and English-bias conditions; the solid lines represent listeners' data; the dashed lines represent the predicted data based on the growth-curve analysis of bilinguals' data (Table 2); the shaded area represents one standard error above and below the mean

Table 2 presents the results of the GCA with the best fit on bilinguals' differential proportions of fixations in all conditions.

Table 2. Results of growth-curve analysis on bilinguals' differential proportions of fixations

		Estimate	**Std. Error**	***t***	***p***
(Intercept)		0.2	0.13	1.5	>.1
Time					
	Linear	4.21	1.09	3.85	**<.001**
	Quadratic	−0.72	0.63	−1.14	>.1
	Cubic	−0.35	0.54	0.65	>.1
English stress		−0.036	0.017	−2.058	**.004**
Language bias		−4.19	1.07	−3.35	**<.001**
Proficiency		0.104	0.159	0.65	>.1
Time x English stress					
	Linear	−0.24	0.216	−1.11	>.1
	Quadratic	0.071	0.226	0.313	>.1
	Cubic	−1.77	0.221	−7.98	**<.001**
Time x Language bias					
	Linear	−1.82	1.745	−1.04	>.1
	Quadratic	2.027	1.004	2.02	**0.049**
	Cubic	−1.19	0.857	−1.4	>.1
Time x Proficiency					
	Linear	−1.44	1.3	−1.11	>.1
	Quadratic	0.75	0.88	1.18	>.1
	Cubic	−1.201	0.638	−1.884	**0.06**
English Stress x Language bias		−0.234	0.027	−8.62	**<.001**
English Stress x Proficiency		0.0327	0.02	1.62	>.1
Language bias x Proficiency		0.062	0.24	0.26	>.1
Time x English stress x Language bias					
	Linear	3.515	0.344	10.21	**<.001**
	Quadratic	0.38	0.361	1.05	>.1
	Cubic	−0.471	0.353	−1.334	>.1
Time x English stress x Proficiency					
	Linear	0.267	0.256	1.045	>.1
	Quadratic	0.259	0.268	0.964	>.1
	Cubic	1.89	0.262	7.218	**<.001**
Time x Language bias x Proficiency					

(*continued*)

Table 2. (*continued*)

		Estimate	Std. Error	*t*	*p*
	Linear	2.334	1.957	1.193	>.1
	Quadratic	−2.29	1.126	−2.042	**0.047**
	Cubic	1.236	0.961	1.286	>.1
English stress x Language bias x Proficiency		0.211	0.03	6.93	**<.001**
Time x English bias x Language bias x Proficiency					
	Linear	−3.547	0.385	−9.21	**<.001**
	Quadratic	−0.374	0.404	−0.926	>.1
	Cubic	0.662	0.395	1.674	**0.094**

Note. $\alpha = .05$; significant results are in bold

The most important effects in Table 2 can be summarized as follows. The simple effect of English stress indicates that the stress-interference condition produced lower proportions of fixations (indicating *more* lexical competition) than the no-stress-interference condition. And the simple effect of language bias indicates that the English-bias condition showed lower proportions of fixations than the Spanish-bias condition.

The two-way interaction between English stress and language bias indicates that the stress effect was larger in the English-bias condition than in the Spanish-bias condition; that is, there were lower proportions of fixations (indicating *more* lexical competition) in the stress-interference condition than in the no-stress-interference condition, and this difference was larger when participants heard more English words as compared to when they heard more Spanish words. Lastly, the GCA model showed the existence of three- and four-way interactions (between English stress, language bias, proficiency, and the time coefficients). The presence of these interactions warranted additional GCAs testing for the effects of time, English stress and proficiency on bilinguals' differential proportions of fixations separately for the English-bias and Spanish-bias conditions. Table 3 presents the results of the follow-up GCAs with the best fit.

Importantly, the GCAs in Table 3 revealed significant effects of English stress and significant interactions between the linear, quadratic, and cubic time polynomials and English stress for *both* the Spanish-bias and the English-bias conditions: The estimates for the effect of English stress indicate that English listeners showed lower proportions of fixations in the stress-interference than in the no-stress-interference condition, an effect that is further emphasized by differences in the shape and form on the two curves, as shown by the interaction between the time polynomials and English stress.

Table 3. Results of GCA on bilinguals' differential proportions of fixations separately for the Spanish-bias and English-bias conditions

			Estimate	**Std. Error**	*t*	*p*
Spanish-bias	(Intercept)		0.2	0.14	1.43	0.17
	Time					
		Linear	4.24	1.03	4.09	**<.001**
		Quadratic	−0.67	0.62	−1.09	>.1
		Cubic	0.27	0.56	0.49	>.1
	English stress		−0.03	0.01	−2.01	**0.04**
	Proficiency		0.11	0.16	0.64	>.1
	Time x English stress					
		Linear	−0.35	0.18	−1.95	**0.05**
		Quadratic	0.1	0.18	0.58	>.1
		Cubic	−1.71	0.18	−9.69	**<.001**
	Time x Proficiency					
		Linear	−1.43	1.23	−1.17	>.1
		Quadratic	0.83	0.73	1.14	>.1
		Cubic	−1.15	0.67	−1.72	>.1
	Stress x Time		0.02	0.02	1.21	>.1
	Time x English stress x Proficiency					
		Linear	0.47	0.21	2.24	**<.05**
		Quadratic	0.16	0.21	0.74	>.1
		Cubic	1.84	0.21	8.79	**<.001**
English-bias	(Intercept)		0.22	0.16	1.38	>.1
	Time					
		Linear	2.04	1.38	1.49	>.1
		Quadratic	1.31	0.79	1.65	>.1
		Cubic	−0.48	0.64	−0.75	>.1
	English stress		−0.30	0.02	−17.56	**<.001**
	Proficiency		0.14	0.17	0.81	>.1
	Time x English stress					
		Linear	3.66	0.22	16.62	**<.001**
		Quadratic	0.48	0.22	2.20	**0.03**
		Cubic	−2.69	0.22	−12.21	**<.001**
	Time x Proficiency					

(*continued*)

Table 3. (*continued*)

		Estimate	Std. Error	t	p
	Linear	1.21	1.48	0.82	>.1
	Quadratic	−1.41	0.85	−1.65	>.1
	Cubic	−0.31	0.69	−0.45	>.1
English stress x Time		0.27	0.02	14.74	**<.001**
Time x English stress x Proficiency					
	Linear	−3.61	0.24	−15.28	**<.001**
	Quadratic	−0.17	0.24	−0.71	>.1
	Cubic	2.98	0.24	12.59	**<.001**

Note. $\alpha = .025$; significant results are in bold

The presence of a three-way interaction between the time polynomials, English stress and proficiency warranted additional GCAs testing for the effects of proficiency on the differential proportions of fixations separately for the stress-interference and no-stress-interference separately (not reported in a table due to length limitations). This interaction, however, indicates that the effect of stress interference was modulated by proficiency in Spanish: As their proficiency in Spanish increased, participants' differential proportions of fixations showed more positive results (indicating *less* lexical competition) only in the stress interference condition; consequently, the effect of stress decreased as proficiency in Spanish increased. This effect emerged in both the Spanish-bias and English-bias conditions, although the interaction was stronger in the English-bias condition ($t = 7.63$) than in the Spanish-bias condition ($t = 3.06$).

These results suggest that bilinguals who were more proficient in Spanish were better able to minimize the interfering effect of English stress.

2.6 Discussion

Focusing on stress interference, this study investigated how L2 proficiency and language bias modulate the degree of cross language activation that bilinguals in a bilingual language mode experience in comprehension. Effects of these two factors have been reported in the literature on bilingual comprehension (e.g., Grosjean, 1998; Guo & Peng, 2006; Ju & Luce, 2004; Marian & Spivey, 2003; Soares & Grosjean, 1984; Spivey & Marian, 1999; Weber & Cutler, 2004). This study also explored whether (and if so, how) these two factors interact.

Bilinguals in the English-bias condition showed more lexical competition in the stress-interference condition than in the no-stress-interference condition, with this effect being modulated by their proficiency in Spanish. These findings are in line with previous comprehension studies looking at the effects of language bias (e.g., Marian & Spivey, 2003a; Spivey & Marian, 1999). Marian & Spivey (2003a) hypothesized that the bilinguals in their first study (Spivey & Marian, 1999), who were tested in both languages in the same experimental session and by fluent bilingual speakers, may have been more sensitive to the similarities between the two languages during the experiment, and thus experienced greater cross-language competition, than the bilinguals in their second study (Marian & Spivey, 2003a), who were tested in only one language and by monolingual speakers. In both studies, though, there was evidence of cross-language activation when the unintended language was the L1 like in the current study.

Not only language bias, but also L2 proficiency was found to affect cross-language activation. As predicted, the effect of stress-interference was modulated by L2 proficiency, with participants showing less lexical competition in the stress-interference condition as their Spanish proficiency increased, particularly so in the English-bias condition. Moreover, L2 proficiency additionally modulated the effect of language bias, with listeners showing a reduced effect of language bias as their proficiency increased, largely due to their enhanced ability to control cross-language activation in the English-bias condition. Previous studies have indeed shown that L2 proficiency modulates cross-language activation from the L1 (e.g., Mishra & Singh, 2016; Silverberg & Samuel, 2004). The current findings thus support the claims that more proficient L2 listeners exert better control over the degree of cross-language activation from the L1, especially when biased towards the unintended language (English bias).

One limitation of the present design is in the interpretation of the nature of the effect of stress shown: It is unclear whether it is an effect of stress interference or stress facilitation. For instance, it could also be the case that the no-stress-interference helped listeners rule out the interference from the English stress pattern as early as in the first syllable (where the English words would have been stressed, unlike what the heard acoustic input showed). This would indicate that being able to inhibit the English stress interference earlier in the word makes it easier for participants to reduce the level of cross-language interference. Possibly, both stress facilitation and stress interference may be observed, depending on the condition. Further research should seek to tease these two possibilities apart. Another limitation is that the speaker heard by participants was a native Spanish speaker who learned English as an L2. This decision was preferred over a simultaneous Spanish-English bilingual because such bilinguals have been shown to produce speech differently from monolinguals in both their languages (e.g., their voice onset time in the two languages often differs from that observed in monolinguals) (e.g., Flege, 1987; Sancier & Fowler, 1997). Since the target language in the present study was Spanish, having a native Spanish speaker whose Spanish was not influenced by English was considered more important than having a speaker whose English was more native-like. However, it is true that this influence could have had an impact on bilinguals' responses, by reducing how much English activation they experienced.

In conclusion, the findings of Experiment 1 indicate that language bias and L2 proficiency modulate the degree of cross-language activation shown by bilinguals, and they interact such that L2 proficiency is more likely to influence cross-language activation when the unintended language is more often used (English bias) than when it is less often used (Spanish bias). Experiment 2, described next, provided a test for determining whether factors such as language bias and L2 proficiency modulate cross-language activation in bilingual speech production when bilinguals are in a bilingual language mode.

3. Experiment 2: Production

3.1 Participants

Same as those described in Experiment 1.

3.2 Materials

The test items of Experiment 2 were the same as those described for Experiment 1. However, the predictions made for the two experiments differ. Whereas the stress-interference condition (e.g., *material* vs. *materia*) was expected to increase lexical competition in comprehension (Experiment 1), it was not expected to interfere with word naming in production (Experiment 2), due to the similarities between the two languages. The basic idea would be that, in production, similarities in stress placement between the cognate word and the real target word (e.g., *materia* and *material*) would produce faster naming latencies, considering that activating the English pronunciation of the cognate word would lead to the correct activation of the target word in Spanish (as both words have second syllable stress). Hence, for Experiment 2, this condition is referred to as the no-stress-interference condition. Half of the test items belonged to this no-stress-interference condition, and the remaining half belonged to a stress-interference condition, where the stress pattern of the English cognate competitor differed from that of the Spanish target (e.g., literal) and thus where interference from the English stress pattern was expected. If participants activated the English stress pattern, they should produce the Spanish target word more slowly and less accurately in the stress-interference condition (e.g., *litera*) than in the no-stress-interference condition (e.g., *materia*).

The same language bias manipulation was used in Experiment 2. As in Experiment 1, participants were assigned to either a Spanish-bias condition or an English-bias condition, whichever condition they were assigned to in Experiment 1. To avoid task effects related to participants' familiarity with the stimuli employed in this study, the presentation of target-competitor word pairs and distracter word pairs was randomized such that even though participants saw the same words in Experiments 1–2, they did not see the same array of four words.

3.3 Procedure

The participants completed the experimental session in a quiet room. Paradigm software (Perception Research Systems, Inc.; Tagliaferri, 2005) was used to present the visual stimuli and record participants' word productions. After Experiment 1, participants first viewed the four orthographic words for 4,000 ms, which they were instructed to silently read. The words then disappeared, and a fixation cross appeared and stayed on the screen for 500 ms. As the fixation point disappeared, the same four words reappeared on the screen, one of them in a circle and in color. Participants were asked to read the circled word aloud in the language signaled by the color, and do so as quickly and accurately as possible. Paradigm saved each individual word production as a separate .wav file, recording from the onset of the screen with the circled word appeared and for 2,000 ms. The recording volume was readjusted before each new participant. Figure 3 presents a visual representation of a trial in both conditions.

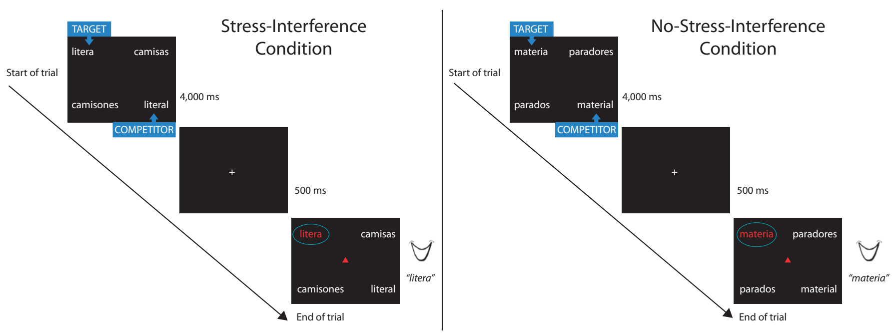

Figure 3. Visual example of two trials in Experiment 2 in the stress-interference and no-stress-interference conditions separately

The language bias in this experiment was created by presenting the target word in one of two colors (red for Spanish and blue for English). Participants were carefully instructed about this color manipulation, and they had a short practice (4 trials) to ensure that they understood this manipulation. Experiment 2 was always completed after Experiment, with at least 2 days in between the two experimental sessions.

3.4 Data analysis

Each individual recording was visually inspected and analyzed using PRAAT (Boersma & Weenink, 2010) to extract naming latencies (from the onset of the screen with the circled word to the onset of the word produced). Word productions affected by false starts or disfluencies read in the wrong language or misread, and words rated as inaccurately stressed by two naïve raters to the purpose of the study were not included in the final analyses (excluding 0.83% of the data). Due to technical problems, the recordings of one participant were not saved, which led to the loss of 2.5% of the data. In total, 4.06% of the data was excluded.

Naming latencies were analyzed with linear mixed-effects models using the lme4 package of R (Baayen, 2008). The models examined the effect of English stress (no-stress-interference vs. stress-interference, with the no-stress-interference condition as the baseline), language bias (Spanish-bias vs. English-bias, with Spanish-bias as the baseline), proficiency (arcsine transformed and centered), and all two- and three-way interactions. For each dataset, the effect of each predictor was assessed using log-likelihood tests comparing models with and without that predictor; in each case, the simplest model with the best fit was kept. All models included participant and test item as crossed random variables.

Experiment 2 explored how factors such as L2 proficiency and language bias modulate the degree of cross-language activation in a production task. If these two factors interact with each other, we could find that the effects of stress and language bias are modulated by L2 proficiency. For stress, such an interaction would be expected to reveal that participants can more easily reduce the degree of cross-language activation in the stress interference condition as their proficiency in their L2 Spanish increases. For language bias, more proficient bilinguals could show less sensitivity to language bias as a result of better controlling for the degree of cross-language activation.

3.5 Results

Figure 4 presents bilinguals' naming latencies in the no-stress-interference (dark grey) and stress-interference (red) conditions, separately for the Spanish-bias and the English-bias groups.

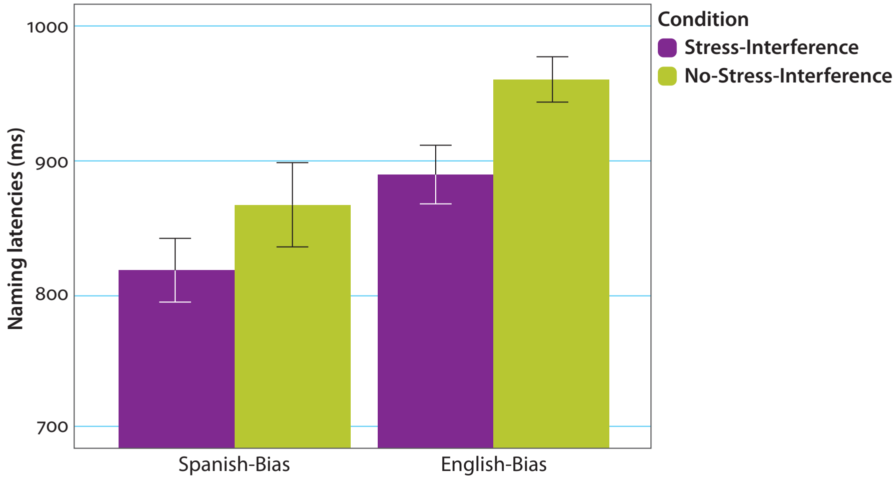

Figure 4. Bilinguals' naming latency results separately for the Spanish-bias and the English-bias condition. Red columns represent the stress-interference condition, while dark grey represent the no-stress-interference

Table 4 presents the results of the linear mixed-effects models with the best fit on bilinguals' naming latencies results in all conditions.

Table 4. Results of mixed-effects linear model results on bilinguals' naming latencies

	Estimate	Std. Error	*t*	*p*
(Intercept)	874.68	98.15	8.91	**<.001**
English stress	−35.29	48.17	<|1|	>.1
Language bias	−59.58	162.27	<|1|	>.1
Proficiency	−59.49	115.8	<|1|	>.1
English stress x Language bias	178.91	80.79	2.21	**<.025**
English stress x Proficiency	97.92	57.05	1.29	>.1
Language bias x Proficiency	144.29	179.87	<|1|	>.1
English stress x Language bias x Proficiency	−206.68	89.26	−2.32	**<.019**

Note. $\alpha = .05$; significant results are in bold

The model summarized in Table 4 revealed a two-way interaction between English stress and language bias, as well as a three-way interaction between English stress, language bias, and proficiency. The two-way interaction between English stress and language bias shows a greater effect of English stress in the English-bias condition than in the Spanish-bias condition. In order to better understand the two- and three-way interactions, linear mixed-effects models were run separately on the two language bias conditions. Table 5 presents the results of the follow-up linear mixed-effects models with the best fit.

Table 5. Results of mixed-effects linear model results on bilinguals' naming latencies separately for the Spanish-bias and English-bias conditions

		Estimate	**Std. Error**	*t*	*p*
Spanish-Bias	(Intercept)	866.12	109.66	7.9	**<.001**
	English stress	−59.78	50.41	<|1|	>.1
	Proficiency	−34.68	50.4	<|1|	>.1
	English stress x Proficiency	102.13	59.72	1.71	<.09
English-Bias	(Intercept)	807.64	110.56	7.31	**<.001**
	English stress	148.1	61.52	2.41	**<.017**
	Proficiency	88.06	117.12	<|1|	>.1
	English stress x Proficiency	−109	65.09s	−1.61	<.097

Note. $\alpha = .025$; significant results are in bold

The results of these follow-up models showed only a simple effect of English stress and only in the English-bias condition. This effect indicates that bilinguals were faster at naming the target word in the no-stress-interference condition than in the stress-interference condition. The trend towards interactions between stress interference and proficiency indicate that the effect of English stress in the Spanish-bias condition is larger with increasing proficiency in Spanish but that in the English-bias condition is smaller with increasing proficiency in Spanish. However, these trends do not reach significance.

3.6 Discussion

Experiment 2 investigated whether (and if so, how) factors such as language bias and L2 proficiency modulate bilingual word production. Previous research on literate bilinguals' word production has consistently shown that language proficiency modulates cross-language activation in word production tasks (e.g., Gollan & Ferreira, 2004; Gollan, Montoya, Cera, & Sandoval, 2008; Hanulová, Davidson, & Indefrey, 2011; Linck, Hoshino, & Kroll, 2008), including when the unintended language is the L2 and the intended language is the L1 (e.g., Gollan & Ferreira, 2004; Towell, Hawkins, & Bazergui, 1996). Considering that the effects of language bias in bilingual word production had not yet been explored, and based on the results of Experiment 1, it was hypothesized that more proficient bilinguals would show a reduced effect of language bias as a result of their control of cross-language activation in the English-bias condition.

Like in Experiment 1, the bilinguals' naming latency results showed an interaction between language bias and English stress condition, with the effect of stress being significant only in the English-bias condition. However, proficiency results did not reach significance. The trend towards interactions between stress interference and proficiency indicate that the effect of English stress is larger in the Spanish-bias condition with increasing proficiency (more competition) and smaller in the English-bias condition (less competition). These mixed effects of proficiency seem to suggest that the interpretation of the nature of the effect of stress shown by bilinguals is not clear, as observed in Experiment 1. It is unclear whether the effect of stress reported is an effect of stress interference (as reported) or of stress facilitation. For instance, it could also be an effect of stress facilitation, with the no-stress-interference condition facilitating the production of the Spanish target, instead of the stress-interference influencing the pattern of results. Possibly, both stress facilitation and stress interference may also be happening on the two conditions. Further research should seek to tease these two possibilities apart.

In conclusion, the findings of Experiment 2 indicate that English stress modulates bilinguals' cross-language activation during bilingual word production, and this effect is modulated by language bias.

4. Discussion and conclusion

This study was designed to further explore how L2 proficiency and language bias affect the way in which bilinguals control the level of activation of their two languages. It was unclear, from previous findings, how both L2 proficiency and language bias would modulate bilinguals' activation of bilinguals' two language systems, whether the two factors would interact, and whether (and if so, how) the degree of involvement of these factors would differ in language comprehension vs. language production.[2]

The results confirmed that language bias modulated cross-language activation in both bilingual word comprehension and word production and that this effect was further modulated by L2 proficiency in comprehension. The results of Experiment 1 (comprehension) and Experiment 2 (production) showed that bilin-

2. The production task (Experiment 2) was created to mirror the format of the visual-world eye-tracking task (Experiment 1). However, considering that these two tasks yielded very different dependent variables (eye movements vs. naming latencies), it was not possible to directly compare the results of the two experiments. For this reason, conclusions are drawn on the basis of whether language bias and L2 proficiency similarly affected performance in comprehension and in production.

guals showed more cross-language activation from the stress interference condition in the English-bias condition than in the Spanish-bias condition, with this cross-language activation decreasing as their proficiency in Spanish increased (in Experiment 1). These results indicate that, the more cross-language interference occurred, the more difficult it was to disambiguate between the Spanish target and competitor words (comprehension) or to retrieve the Spanish target over its competitor (production). Experiments 1 and 2 provide one of the first attempts to compare how factors such as language bias and L2 proficiency modulate cross-language activation in bilingual word comprehension and word production.

Language bias and L2 proficiency had already been proposed as factors modulating the level of cross-language interference reported in the bilingual language comprehension and language production literature (e.g., Grosjean, 1997; Guo & Peng, 2006; Ju & Luce, 2004; Marian & Spivey, 2003a; Soares & Grosjean, 1984; Spivey & Marian, 1999; Weber & Cutler, 2004). Consistent with previous findings, this study showed how both L2 proficiency and language bias are important factors when understanding bilingual activation. However, as results from this study suggest, L2 proficiency and language bias are not two independent factors, but they interact with each other. the results of the current study are consistent with previous studies in which bilinguals are better at controlling for the degree of cross-language activation, thus reducing the effect of language bias as their L2 proficiency increases, consistent with previous findings. Moreover, this study investigated whether the degree of involvement of these factors would differ in language comprehension vs. language production: It showed that language production is as likely to show evidence of cross-language activation as language comprehension and that the effect of L2 proficiency is stronger in bilingual word comprehension than in bilingual word production. However, these results need to be taken with caution, as using a different proficiency measure (e.g., a phonological awareness task) could show different results.

These findings are consistent with the cross-linguistics interference account of lexical access difficulties in bilinguals, which suggests that when cross-linguistic competition is reduced (e.g., providing them with predictive sentence contexts), bilinguals should not show any disadvantage in lexical access as compared with monolingual speakers (e.g., Chambers & Cooke, 2009; Desmet & Duyck, 2007; Lagrou, Hartsuiker, & Duyck, 2013a, 2013b; Libben & Titone, 2009; Schwartz & Kroll, 2006). In fact, sentence context, even when not predictive of the target, can result in decreased activation of cross-language competitors (e.g., Chambers & Cooke, 2009; Titone, Libben, Mercier, Whitford, & Pivneva, 2011). This contextual information would operate as a language bias filter (biasing bilinguals towards one language and one semantic interpretation), and hence it is reasonable to think that this filter may be harder to operate as L2 proficiency increases (more activation of the unintended language could lead to more garden-path interpretations of these sentences) or even the opposite pattern, with increased L2 proficiency it could more easily modulate the cross-language interference, in line with this study. Further research should explore how different factors (including language bias and L2 proficiency) interact and affect the way in which bilinguals operate their two language systems. Importantly, there may be other factors that may be further influencing the degree of cross-language activation in the bilinguals examined in this study, e.g., individual differences in inhibitory control, as proposed by the Inhibitory Control Model (Green, 1998). The main purpose of the study was to explore how factors modulating bilingual activation interact with each other. However, further studies need to explore the role of inhibitory control and how it interacts with other factors such as proficiency and/or language bias.

One additional question that remains open for further research is how the directionality of a language switch affects cross-language activation. Experiments 1 and 2 contained both Spanish targets and English targets. This means that in both experiments, there were instances of language switch vs. no-language switch, with some Spanish trials immediately following an English trial (language switch) and with other Spanish trials immediately following a Spanish trial (no language switch). This aspect was not controlled in the current study, so the number of language-switch trials and no-language-switch trials was not perfectly distributed across conditions and groups. On the one hand, this prevented a robust analysis of the data with language switch as a predictor of participants' responses; on the other hand, this raises the question of whether some of the effects reported in this study could be attributed in part to language switch. For most conditions and groups, the distribution of experimental items that initiated vs. did not initiate a language switch was not significantly different between the stress-interference and no-stress-interference conditions. Thus, the nature of the effects of English stress reported here seems to be robust. Future studies should try to tease apart the contributions of language bias and language switch in the modulation of cross-language activation.

The present study provided a systematic investigation of how both L2 proficiency and language bias modulate bilinguals' activation of their two language systems, whether the two factors interact, and whether (and if so, how) the degree of involvement of these factors differ in language comprehension vs. language production. However, it is just a first step towards understanding the mechanisms that bilinguals employ to control the level of activation of their two languages. More research is needed in order to further understand how additional factors such as language switch and inhibitory control interact with those investigated in this study, and the implications that these effects may have for the use of bottom-up and top-down mechanisms in bilingual activation.

Appendix A. Target, competitor, and distracter words in critical test items

Table A1. Words in the stress-interference (Experiment 1) and no-stress-interference (Experiment 2) conditions

	Target (second syllable stress in Spanish)	Competitor (final syllable stress in Spanish)	Distracter 1	Distracter 2
1	colonia (colony/cologne)	colonial (colonial)	helado (ice-cream)	helador (freezing)
2	evento (event)	eventual (eventual)	mirada (look)	mirador (viewpoint)
3	electo (elected)	elector (elector)	paloma (pidgeon)	palomar (dovecote)
4	directo (direct)	director (director)	parroquia (parish)	parroquial (parochial)
5	selecto (selected)	selector (selector)	asado (roast)	asador (rotisserie)
6	idea (idea)	ideal (ideal)	pesado (heavy, masc)	pesadez (bore)
7	industria (industry)	industrial (industrial)	pescado (fish)	pescador (fisherman)
8	invento (invent)	inventor (inventor)	ventana (window)	ventanal (picture window)
9	notario (notary)	notarial (notarial)	portada (cover)	portador (carrier)
10	materia (subject/matter)	material (material)	seguido (straight)	seguidor (fan)
11	familia (family)	familiar (familiar)	pasado (past)	pasador (hairclip)
12	tribuna (tribune)	tribunal (tribunal)	marisco (seafood)	mariscal (marshal)

Table A2. Words in the no-stress-interference (Experiment 1) and stress-interference (Experiment 2) conditions

	Target (second syllable stress in Spanish)	Competitor (final syllable stress in Spanish)	Distracter 1	Distracter 2
1	principio (principle)	principal (principal)	camisa (shirt)	camisón (nightshirt)
2	persona (person)	personal (personal)	comuna (commune)	comunión (communion)
3	labrado (cultivated)	labrador (labrador)	espada (sword)	espadón (broadsword)
4	angula (elver)	angular (angular)	maduro (mature)	madurez (maturity)
5	alcoba (alcove)	alcohol (alcohol)	ganado (cattle/won)	ganador (winner)
6	audible (audible)	auditor (auditor)	caricia (caress)	caridad (charity)
7	flexible (flexible)	flexional (flexional)	comicio (election)	comisión (commission)
8	termita (termite)	terminal (terminal)	dinero (money)	dineral (fortune)
9	litera (bunk bed)	literal (literal)	otoño (fall, n)	otoñal (fall, adj)
10	minero (miner, masc)	mineral (mineral)	chupete (pacifier)	chupetón (slurp)
11	natura (nature)	natural (natural)	obispo (bishop)	obispal (related to bishops)
12	cultura (culture)	cultural (cultural)	vecino (neighbor)	vecinal (neighboring)

Appendix B. Listeners' proportions of target, competitor, and distracter fixations

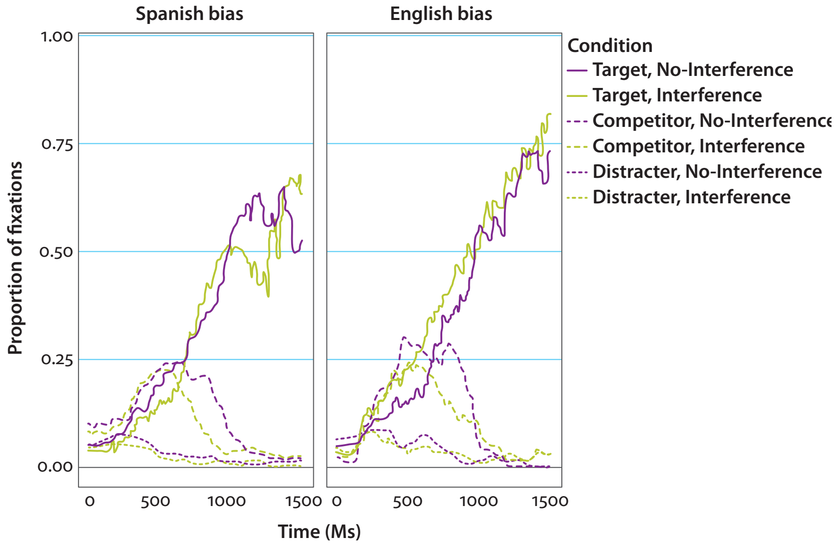

Figure B1. Bilinguals' proportions of target, competitor, and distracter fixations in the stress-interference and no-stress-interference conditions, separately for the English-bias and Spanish-bias conditions; the shaded area represents one standard error above and below the mean

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