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When it's harder to *ignorar* than to ignore: Evidence of greater attentional capture from a non-dominant language

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Abstract

Aims and Objectives: Imagine you're driving and you become so distracted by the radio that you miss your turn. Which is more likely to have caught your attention, a broadcast in your native tongue or one in your second language? The present study explores the effect of language proficiency on our ability to inhibit irrelevant phonological information.
Methodology: Participants were asked to identify which of two drawings changed color while ignoring irrelevant words in either their native language, English, or a less proficient language, Spanish. The drawings appeared on screen for either 200 or 2000 ms prior to word-onset, which was followed 200 ms later by a color-change. On critical trials, the irrelevant word shared phonological features with the label of the non-target drawing. Trials were blocked by preview time and language.
Data and Analysis: Reaction time data from 19 bilinguals were analyzed utilizing generalized linear mixed-effects models, with fixed effects of Competition (competitor vs. control), and Language (English vs. Spanish) and random effects for Subject and Item within each preview window.
Findings/Conclusions: No interference was observed when participants heard their native tongue in either preview condition. However, participants in the long-preview condition were significantly slower to respond when there was phonological competition in their less proficient language, despite the fact that the task required no language processing.
Originality: Past work has indicated that languages are processed more automatically and cause greater interference as proficiency increases. We propose that though higher-proficiency languages may receive greater activation overall, lower-proficiency languages may be more likely to exogenously capture attention due to both relatively greater salience, and relatively less control.
Significance: The present findings have implications for how we understand the dynamic relationship between language proficiency, activation, and inhibition, suggesting that the salience of the less familiar influences our ability to ignore irrelevant information.

Keywords

Bilingualism, phonological interference, attention, language activation, proficiency

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Introduction

Language processing is often thought of in the context of deliberate activities, such as reading the news or having a conversation. Yet in many cases we process language without any effort or choice (e.g. Moray, 1959). A piano concerto may help set the mood when enjoying a novel, but background speech is likely to be disruptive (Martin et al., 1988). We may be fully engrossed in an activity, but our attention can be diverted to a neighbor's conversation or, quite advantageously, to someone issuing a warning or a cry for help (e.g. Chang & Thompson, 2010; Mathews & MacLeod, 1986). However, not all stimuli are equally likely to capture our attention. For instance, it is more likely that we would notice self-relevant information such as our own name than some other less personal stimulus (e.g. "the cocktail party effect"; Cherry, 1953; Cherry & Taylor, 1954; Moray, 1959; Wood & Cowan, 1995). Here, we explore whether the extent to which language can capture our attention (and potentially interfere with other tasks) depends on our level of linguistic experience and expertise.

There is good reason to think that it would be hardest to ignore a more dominant language – one for which we have the highest proficiency and the most practice. According to Treisman's (1960) attenuated filter model, information from unattended channels can reach awareness if the stimulus representation receives sufficient activation. Certain words, Treisman argues, may be more readily activated than others. For instance, one's own name and words that signal danger (e.g. "fire") likely receive higher levels of activation, and are subsequently more likely to be detected even when unattended. To the extent that higher proficiency results in greater activation, we may expect higher-proficiency languages to capture attention more readily than less proficient languages. Indeed, there is evidence that this is often the case. For instance, it has been found that color words in a dominant L1 cause more interference during Stroop tasks than color words in L2, particularly for lower-proficiency L2 speakers (Chen & Ho, 1986; Mägiste, 1984). Further evidence of greater L1 activation can be found by examining the relative influences that two languages have on each other. Because bilinguals activate both languages even when only one is in use (Marian & Spivey, 2003; Shook & Marian, 2012), cognates between the two languages can facilitate lexical retrieval (Costa et al., 2000; Dijkstra et al., 1999; Kroll et al., 2006). Critically, both Costa et al. and Kroll et al. found that the facilitation from L1 to L2 was more pronounced than from L2 to L1.

Similar evidence has been found using the Visual World Paradigm (VWP), in which participants are presented with sets of visual stimuli, some of which overlap with an auditory stimulus along a particular dimension (e.g. phonologically: the word "beaker" – image of a *beetle;* Allopenna et al., 1998; semantically: "lock" – *key;* Yee & Sedivy, 2006; visually: "snake" – *cable;* Huettig & Altmann, 2007, 2011). By examining the pattern of eye-movements to objects that share similarities with the target, it is possible to identify what representations become activated in response to a particular stimulus (see Huettig et al. (2011) and Mishra (2009) for reviews). Using the VWP, Marian and Spivey (2003) found that when Russian-English bilinguals are asked to click on a "marker," they will often make eye-movements towards a picture of a stamp (*marka* in Russian), demonstrating that bilinguals activate phonological features of both languages even when only one is in use. Indeed, overlapping phonology with even newly acquired artificial languages can result in interference and delayed response times (Bartolotti & Marian, 2012). Relevant to the current investigation, it has been found that conflict is most likely to arise from the unintentional activation of a dominant language during a non-dominant language task (Blumenfeld & Marian, 2007). This pattern is consistent with the idea that the higher-proficiency language receives greater activation, and may therefore be harder to ignore.

On the other hand, there are also reasons to think that lower-proficiency languages may capture attention to a greater degree than higher-proficiency languages. For instance, a less practiced language may grab attention due to its relative novelty or salience (Buchner et al., 2004; Cavicchio et al., 2014). Buchner and Erdfelder (2005) found that rare, low-frequency distractor words caused more interference than high-frequency distractors when trying to recall target words. The authors explain this finding in the context of Cowan's (1995) attention-and-memory framework that stipulates that performance on a primary task will be disrupted if attentional resources are redirected to stimuli that exogenously capture attention. Processing rare words likely captures more attention than familiar words, and may therefore be more disruptive to a primary task. A less familiar language may similarly capture attention to a greater degree than a more familiar language. Additionally, because the everyday use of a less fluent language may require more attentional resources, individuals may become especially receptive to it in order to compensate for their lower proficiency. A similar explanation was put forth by Costa and Santesteban (2004) to explain a curious finding that participants were faster at naming objects in their L2 and L3 than in their L1. The authors propose that individuals may try to compensate for lower proficiency by making lexical representations more available when producing a less proficient language.

In addition to less familiar languages capturing more attention, dominant languages may be inhibited to a greater degree. According to the Inhibitory Control model of bilingual speech production (Green, 1998), inhibition of non-target languages is reactive and proportional to the amount of activation they receive. In other words, more proficient languages receive greater activation and therefore require more inhibition. In support of this theory, Meuter and Allport (1999) found that participants took longer to switch from a non-dominant language into a dominant language than vice versa during language production. It may therefore be the case that individuals become more practiced at inhibiting their more proficient tongue, not only in cases where it would interfere with a less proficient language, but also when it would interfere with a non-linguistic task. A similar idea was proposed by Tzelgov et al. (1990) who suggested that as proficiency in a language increases, one could expect an increase in both automaticity (i.e. activation) and the skills needed to control the language (i.e. inhibition). In keeping with this idea, the authors found that interference during a Stroop task could be reduced in a native language so long as the language of input was expected, whereas no such reduction was seen in the non-native language. This pattern is consistent with the idea that while greater proficiency in a language may increase its activation, it may additionally be under stricter control. Greater inhibition of L1 as compared to L2 has also been found during language comprehension (i.e. greater switch costs from L2 to L1 than vice versa; Ibáñez et al., 2010), though the reverse pattern has also been observed (i.e. greater switch costs from L1 to L2; Proverbio et al., 2004), suggesting that the effect of language proficiency on inhibition may differ during language comprehension and production.

What is yet unclear is the extent to which language proficiency affects inhibition during a task that requires neither language production nor comprehension – that is, cases in which linguistic stimuli must be ignored, not in order to retrieve other linguistic representations, but to perform a nonlinguistic task. Using a VWP, Chabal and Marian (2015) found that when participants were tasked with finding an object that was previously shown to them (e.g. a clock), English and Spanish speakers were distracted by items that had phonologically similar labels in their respective languages (e.g. clock/cloud or *reloj/regalo*). This finding demonstrates that phonological features of a language can become activated even when no language is explicitly introduced in the task. Similar effects have been found even when a task requires only the most basic perceptual processing of a visual target (Allopenna et al., 1998; Salverda & Altmann, 2011). Salverda and Altmann had participants identify which object in a display changed color or moved, while ignoring a concurrently played auditory word. In critical trials, the concurrent word was the label of the non-target object. Presentation of the spoken word caused participants' saccade latencies to increase, indicating that there was interference from the auditory distractor. This suggests that the integration of linguistic and visual input is automatic, and that it occurs even when attention to linguistic input is unnecessary or even detrimental. Our question is whether the extent to which people experience phonological competition as a result of automatic language processing varies as a function of their linguistic expertise. In other words, is a more proficient language harder or easier to ignore?

In addition to the effects of language proficiency, we include an exploratory investigation into whether the extent of linguistic interference varies depending on individual differences in cognitive abilities (e.g. inhibitory control, working memory). Previous research using linguistic interference tasks has found that target identification is facilitated by greater executive control (e.g. Blumenfeld & Marian, 2011; Chabal & Marian, 2015), likely due to more efficient inhibition of distractors and/or facilitation of targets. Working memory has also been shown to facilitate visual search, potentially through better maintenance of goals and target stimuli in memory (Kane et al., 2006), more efficient binding of linguistic and sensory representations (Huettig et al., 2011), as well as enhanced selective attention (Lavie & De Fockert, 2005), particularly over sustained periods of time (Poole & Kane, 2009). To the extent that working memory supports attentional control, we may expect that those with greater working memory would be more successful at ignoring irrelevant auditory input, resulting in faster target identification times. In contrast, better maintenance of target representations may not provide a notable advantage for tasks in which participants simply identify a perceptual change (e.g. color; Salverda & Altmann, 2011) rather than a particular object. Indeed, given that interference likely results from the maintenance and integration of representations associated with the *competitor* (e.g. visual, linguistic, and spatial information; see Huettig et al., 2011; Woodman & Luck, 2004), greater working memory may, in fact, exacerbate phonological interference.

To examine the effects of language experience and cognitive abilities on phonological competition, we adapted the paradigm utilized by Salverda and Altmann (2011). As in their experiment, participants were tasked with identifying which object changed color while trying to ignore an auditory stimulus. In contrast to the original study, however, the auditory speech on critical trials did not directly name the non-target object, but rather shared phonology with it. By doing so, we attempted to observe not only language activation, but the extent to which activation spreads to phonological neighbors, thereby isolating the activation of phono-lexical information (looks to directly named objects likely result from the combined effects of phonological and semantic activation). Critically, the words were presented in either English, the dominant, higher-proficiency language, or Spanish, a non-dominant, but highly proficient language. Lastly, the paradigm was adjusted to vary the length of the preview period, which was the time between when participants first saw the objects and when they heard the auditory word. We adopted two preview windows, either 200 ms or 2000 ms, in order to determine whether the effect of phonological competition differed across temporal stages of processing. Past research has suggested that phonological competition may require approximately 300 ms to arise (Huettig & McQueen, 2007). Therefore, we may expect language differences to emerge only in the long preview window after participants have had sufficient time to activate the phonological features associated with the visual objects.

Methods

Participants

Twenty-seven bilingual English-Spanish speakers participated in the study. Three participants were removed due to low performance on a test of Spanish proficiency (the LexTALE- Español; Izura et al., 2014), two participants were removed due to high proficiency in another Romance language, and three were removed due to technical difficulties with the recording computer. The remaining 19 participants (17 female) had an average age of 24.21 (SD = 5.28). As can be seen in Table 1, participants were significantly more proficient in English than in Spanish and reported greater exposure, use, and preference for English. English was more likely than Spanish to have been acquired through family, while Spanish was more likely than English to have been acquired through self-instruction. There was no significant difference for age of acquisition.

Table 1. Means and standard deviations of language background measures.

		English	Spanish	p-value
Proficiency	Comprehension (0–10)[a]	9.47 (0.90)	8.42 (1.22)	0.011*
	Speaking (0–10)	8.93 (1.53)	7.5 (1.56)	0.024*
	Reading (0–10)	9.27 (1.17)	7.79 (1.67)	0.005**
	Vocabulary[b]	113.87 (14.12)	67.42 (12.62)	–
Use	Current exposure (%)[c]	71.73 (22.56)	25.93 (20.02)	0.001**
	Residence in English/Spanish-speaking country (years)	19.80 (9.86)	7.27 (9.82)	0.016*
	Use with friends and family (0–10)	7.57 (2.69)	4.46 (3.61)	0.027*
	Preference for speaking (%)	56.60 (25.81)	38.40 (22.37)	0.085
	Preference for reading (%)	69.60 (28.09)	27.40 (25.47)	0.004**
Acquisition	Age of acquisition (years)	3.11 (4.70)	5.53 (6.23)	0.280
	Acquisition through family (0–10)	8.71 (2.23)	4.64 (4.94)	0.018*
	Acquisition through self-instruction (0–10)	1.14 (2.42)	4.29 (3.01)	0.004**

Note: English vocabulary was assessed using the cognitive battery of the NIH toolbox (Weintraub et al., 2013) and Spanish vocabulary was assessed with the LexTALE-Esp (Izura et al., 2014). Due to the different measures, a direct comparison of these measures was not possible. All other measures were assessed with the *Language Experience and Proficiency Questionnaire* (LEAP-Q; Marian et al., 2007). The final column displays p-values for paired t-tests comparing English to Spanish.
[a]For scales ranging from 0 to 10, higher numbers indicate greater proficiency (0 = none, 10 = perfect), use (0 = never, 10 = always), and contributions to acquisition (0 = not a contributor, 10 = most important contributor).
[b]English vocabulary was assessed using the picture vocabulary test included in the cognitive battery of the NIH toolbox (Weintraub et al., 2013). Using a computerized adaptive format, participants were presented with an auditory word and asked to select an image that most closely represents its meaning. The age-corrected standard score has a normative mean of 100 and a standard deviation of 15, providing an index of receptive vocabulary relative to the national average. Spanish vocabulary was assessed with the LexTALE-Esp (Izura et al., 2014), a lexical decision task in which participants responded to 60 words and 30 nonwords. The weighted average percentage of hits (N_{yes}/60) and correct rejections (N_{no}/30) were calculated to obtain a score ranging from 0 to 100.
[c]The percentage of current exposure captures the relative amount of exposure to each known language, with the percentages adding to 100% across languages.
**$p<.01$; *$p<.05$.

Procedure

Participants were tasked with identifying which of two drawings changed color. Each trial began with a fixation cross that remained on screen for 1000 ms. Two black and white line drawings then appeared on either side of a fixation cross. The images remained on screen for either 200 ms (short preview) or 2000 ms (long preview) before an auditory word was presented over headphones. During the trials, the aurally presented word was either phonologically similar (competitor) or dissimilar (control) to the label of the non-target image, and was presented in either English or Spanish. Phonological overlap always occurred within the same language, so that an English auditory word (e.g. “candy”) could share phonology with an English object label (e.g. *candle*), and a Spanish auditory word (e.g. “boleto”) could share phonology with a Spanish object label (e.g. *bolsillo*). Each language therefore had distinct sets of auditory and visual stimuli (see Appendix for lists of all stimuli used in the study). Though cross-linguistic competitors were not present in the displays, the automatic activation of object labels in the non-target language could potentially dilute the amount of phonological competition in the target language. In order to minimize unintended interference from the unused language, the trials were blocked by language, and participants were prepared for upcoming language switches. Furthermore, in order to provide the most conservative test of the hypothesis that visual discrimination would be more disrupted by hearing Spanish (the less proficient language) than English, the Spanish trials were presented after English trials within each preview window. Otherwise, the predicted pattern could result from prior exposure to Spanish, which could prime participants to activate Spanish during English trials and artificially dilute the effect of English competition. In contrast, if greater competition is observed for Spanish following exposure to English, this would be in spite of potentially inflated English activation (note that covert activation of English labels was expected to naturally exceed that of Spanish due to higher levels of English proficiency; see Blumenfeld & Marian, 2007). Table 2 provides examples of the stimuli.

Table 2. Example stimuli.

Condition	Target image	Distractor image	Auditory word
Competitor - English	paintbrush	squirrel	"squid"
Control - English	notebook	screwdriver	"leak"
Competitor - Spanish	camisa (*shirt*)	arroz (*rice*)	"arroyo" (*stream*)
Control - Spanish	arado (*plow*)	carpeta (*folder*)	"impuesto" (*tax*)

The target image changed from black to green 200 ms after the onset of the auditory word. Both images disappeared after another 200 ms and the trial concluded after the participant indicated which image changed color by pressing the left shift key (left item) or the right shift key (right item). Though participants were free to scan the screen during the trial, they were instructed to focus on the center fixation cross at the start and end of each trial. The order of items within each language block and the location of the target image were counterbalanced. Figure 1 depicts a single trial's timeline. At the end of the experiment, participants provided labels for all images in the appropriate languages and completed the LexTALE-Esp to assess Spanish proficiency and the LEAP-Q to assess language background.

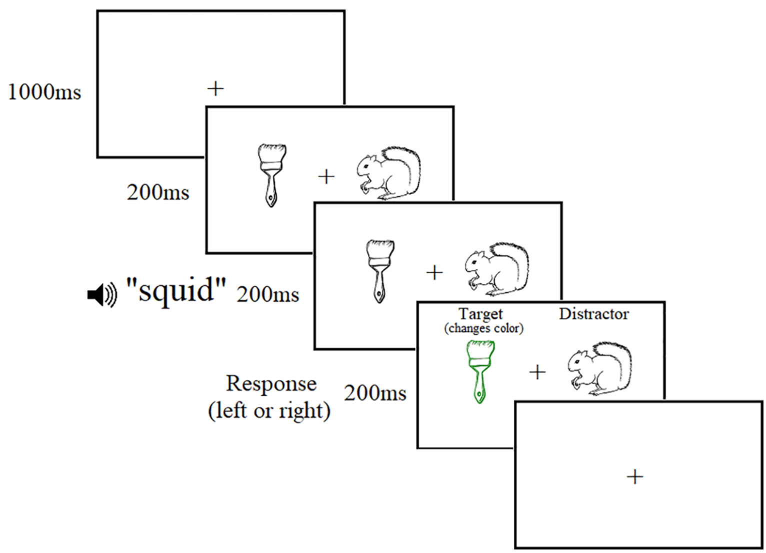

Figure 1. Example of an experimental trial in the competitor-English condition.

There were five practice trials and 20 trials of each condition resulting in 80 experimental trials in each preview window (160 experimental trials in total). Recall that the two preview windows were included to observe whether the effects of language would be moderated by how much time participants had to activate the phonological labels associated with the visual objects. As the same stimuli were used in both preview conditions, short preview trials were presented first in order to avoid any residual activation of labels from long preview trials. Participants then completed the Weschler Scale of Abbreviated Intelligence (WASI; Wechsler, 1999) and the Cognitive Battery of the NIH Toolbox (Weintraub et al., 2013), followed by long preview trials.

Materials

One-hundred and sixty images were used to create 80 visual stimulus pairs. Black and white line drawings were obtained for each item from the International Picture Naming Database (IPNP; Bates et al., 2003) or from Google Images. Images obtained from the IPNP were selected based on high naming consistency, while pictures obtained from Google Images were independently normed by 20 English monolinguals and 20 Spanish-English bilinguals on Amazon's Mechanical Turk (https://www.mturk.com). All images had a naming consistency greater than 70% for both languages (English $M = 93.0\%$, $SD = 7.9\%$; Spanish $M = 91.6\%$, $SD = 8.6$).

Auditory stimuli were recorded by a female, Spanish-English bilingual speaker at 44.1 kHz, and were amplitude normalized to ensure consistent volume, and trimmed to ensure no silence was present at the beginning or end of each sound file. Within each condition, the target images, non-target images, and spoken words were matched on word frequency in English (SUBTLEX-US; Brysbaert & New, 2009; $p > 0.1$) and Spanish (SUBTLEX-ESP; Cuetos et al., 2011; $p > 0.1$). In the control conditions, none of the auditory stimuli (or their translations) had overlapping phonological onsets with the labels for the target or non-target images. In the competitor conditions, the average onset overlap (contiguous phonemes) between the auditory stimuli and the non-target labels was the same in the two languages (English: $M = 2.45$, $SD = 0.61$; Spanish: $M = 2.45$, $SD = 0.51$), while there was no onset overlap between auditory stimuli and target labels.

Data analysis

The dependent measure was button-press reaction time (RT). Trials were excluded if the response was incorrect (1.9% in short preview; 1.5% in long preview), faster than 250 ms from the time that the object changed color (3.1% in short; 1.9% in long), slower than 2.5 standard deviations from that participant's mean in that condition (2.8% in short; 2.1% in long), or if a distractor image in either of the competitor conditions was incorrectly labeled by the participant (12.6% in short; 12.1% in long), resulting in a total of 20.4% of trials being excluded from the short preview analyses and 17.6% from long. The minimum RT of 250 ms was chosen based on saccade latencies reported by Salverda and Altmann (2011; Experiment 1) using a nearly identical color change detection paradigm. The authors found that participants in the fastest "congruent" condition (in which an irrelevant auditory stimulus facilitated looks to the target) took an average of 292 ms to initiate an eye-movement towards the target image following a color change. Trials in which the participant incorrectly labeled the objects were excluded because phonological interference could not be expected if the auditory word and the distractor image did not share phonological features. In total, 2,462 trials were included in the analysis (1210 in short preview; 1252 in long preview).

Results

Competition, language, and proficiency

Raw RT data was analyzed utilizing generalized linear mixed-effects models with an inverse-Gaussian distribution and identity link (see Lo & Andrews, 2015 for recommended analyses of non-normally distributed RT data). Models were fitted with the "lme4" package (Bates et al., 2015) and significance was tested with the Satterthwaite approximation for degrees of freedom using the "lmerTest" package (Kuznetsova et al., 2017). Follow-up tests were run using the "lsmeans" package (Lenth, 2016) to obtain estimates of marginal means and slopes.

The initial model including fixed effects of Competition (Control, Competitor), Language (English, Spanish), and Preview (Short, Long) failed to converge even with a minimal intercept-only random-effects structure. As such, we began by running separate analyses for each preview window. Within each window, RT on each trial was entered as the outcome variable with fixed effects of Competition and Language, which were effect-coded (and weighted by the number of observations) using the following contrasts: Control (–.42) vs. Competitor (+.58) and English (–.45) vs. Spanish (+.55). We began with the maximal random-effects structure, and convergence errors were resolved by examining the partially converged models and progressively removing random-effect terms that explained the least amount of variance until convergence was achieved (see Barr et al., 2013). Ultimately, the short preview model retained a random intercept for Subject, and the long preview model retained random intercepts for Subject and Item (note that by-subject random slopes for Competition and Language were included in subsequent follow-up analyses).

In the short preview condition, there was a main effect of language with participants taking longer to respond in Spanish than in English (*Estimate* = 10.60, *SE* = 4.21, t = 2.52, p = 0.012). There was no main effect of competition (*Estimate* = 0.38, *SE* = 4.22, t = 0.09, p = 0.928), nor an interaction (*Estimate* = 7.95, *SE* = 8.54, t = 0.93, p = 0.352). In the long preview condition, there was a main effect of language (*Estimate* = 20.33, *SE* = 7.96, t = 2.55, p = .011), no main effect of competition (*Estimate* = 10.33, *SE* = 7.94, t = 1.30, p = .193), and most critically, a significant competition x language interaction (*Estimate* = 34.56, *SE* = 15.90, t = 2.17, p = .029). Bonferroni-adjusted post-hoc tests assessing the effects of competition for each language revealed a significant effect of competition for Spanish (*Estimate* = 29.54, *SE* = 11.47, z = 2.58, p = .020; see Figure 2), but no effect for English (*Estimate* = –5.02, *SE* = 10.98, z = –0.46, $p > .9$).

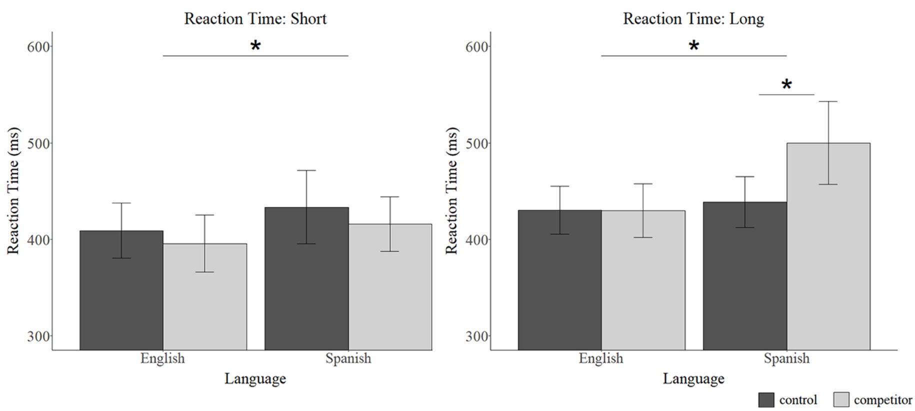

Figure 2. Mean reaction times (ms) for trials with phonological competitors and controls in English and Spanish. Error bars represent standard errors. Asterisks represent significant effects at $p < 0.05$.

Given that the average comprehension proficiency (the measure most relevant to the present task) was lower in Spanish than English (F(1,18) = 8.07, p = 0.011), the pattern of results in the long preview window is consistent with the notion that there is greater phonological interference from a less proficient language. To more directly test this claim, we reran the analysis in the long preview window with fixed effects of Language, Competition, Spanish Proficiency, English Proficiency, and all interactions, with random intercepts for Subject and Item and by-subject random slopes for Language and Competition. Each proficiency score was mean-centered, with positive values representing higher-than-average proficiency within a given language (i.e. raw Spanish – mean Spanish and raw English – mean English).

The critical interaction between language and competition remained significant (*Estimate* = 37.83, *SE* = 14.71, t = 2.57, p = .010). There was additionally a marginally significant language × Spanish proficiency interaction (*Estimate* = –26.06, *SE* = 14.49, t = –1.80, p =.072), such that the overall difference in RT between the two languages was reduced with higher levels of Spanish proficiency. Though the simple effect of Spanish proficiency was not significant for either English (*Estimate* = 33.81, *SE* = 27.5, z = 1.23, p = 0.441) or Spanish trials (*Estimate* = 6.77, *SE* = 32.02, z = 0.21, $p > .9$), the marginal interaction was primarily driven by slower RTs in English with higher levels of Spanish proficiency. Most importantly, we observed a significant language × competitor × Spanish proficiency interaction (*Estimate* = –15.13, *SE* = 7.56, t = –2.00, p = .045), with the size of the language effect on phonological interference decreasing with higher levels of Spanish proficiency (all other effects $p > .05$). Though the lower order effects of Spanish proficiency did not reach significance, the interaction resulted from the relatively larger effect of Spanish proficiency on the Spanish competitor effect (Competitor – Control; *Estimate* = –14.45, *SE* = 9.96, z = –1.45, p = .147) than the English competitor effect (*Estimate* = 0.68, *SE* = 8.71, z = 0.08, p = .938). The correlations between Spanish proficiency and competitor effects in each language (calculated by subtracting mean RTs on control trials from competitor trials) revealed a marginal negative association between Spanish proficiency and Spanish competition (r = –.40, $t(17)$ = –1.81, p = .088), but not English competition (r = .28, $t(17)$ = 1.18, p = .254). As a result, the difference between Spanish and English competitor effects was reduced with higher levels of Spanish proficiency (r = –.45, $t(17)$ = –2.09, p = .052; see Figure 3). Consistent with the regression analysis, we observed no correlation between English proficiency and either Spanish (r = 0.01, $t(17)$ = 0.06, p = .957) or English (r = 0.13, $t(17)$ = 0.53, p = 0.604) competitor effects, potentially as a result of generally higher proficiency and less variability in the dominant language. Together, these findings indicate that as participants become more proficient in their non-dominant language (Spanish), they are similarly affected (or rather, unaffected) by phonological competition in their two languages.

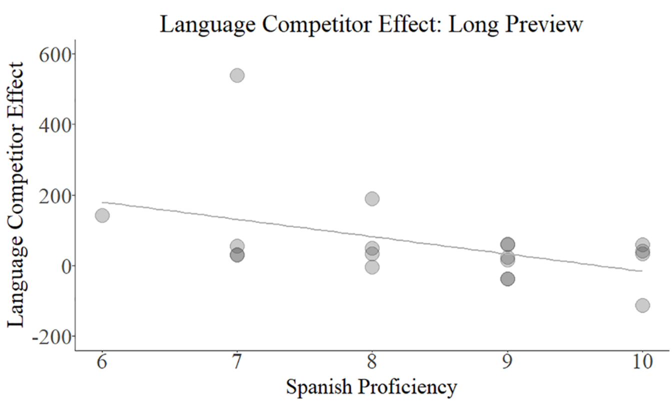

Figure 3. The relationship between Spanish proficiency and the effect of language on the competitor effect (ms). This latter measure was calculated as: (Spanish Competition – Spanish Control) – (English Competition – English Control). Positive values on the Y-axis represent a larger competitor effect in Spanish relative to English. Each dot represents a single participant (N = 19) and the dashed line represents the linear trend.

Lastly, in order to examine whether language and competitor effects vary as a function of *relative* language proficiency, we built a model including fixed effects of Competition, Language, and Relative English Proficiency (English proficiency – Spanish proficiency, mean-centered after subtraction), with the ultimately converging model including a random intercept for Subject and by-subject random slopes for Competition and Language. The critical interaction between language and competition remained significant (*Estimate* = 43.61, *SE* = 7.96, t = 5.48, $p < .001$), and there was a significant interaction between language and relative proficiency (*Estimate* = 21.45, *SE* = 10.64, t = 2.02, p = .043), which was not qualified by competition (*Estimate* = 3.76, *SE* = 5.43, t = 0.69, p = .488). Though the simple effects of relative proficiency were not significant for either language, relatively greater proficiency in English was associated with faster RTs on English trials (*Estimate* = –15.23, *SE* = 19.62, z = 0.78, p = .892), and slower RTs on Spanish trials (*Estimate* = 6.5, *SE* = 23.26, z = 0.28, $p > .9$). Together, these findings indicate that relatively more balanced proficiency in the two languages results in smaller language differences in overall RT, whereas greater proficiency in Spanish is associated with smaller language differences in competitor effects.

Language, competition, and cognitive measures

After the primary analyses, we examined whether any of the individual difference measures affected performance on the visual discrimination task or interacted with the competition and language effects. These measures included non-verbal IQ (WASI), as well as inhibitory control (Flanker), working memory (List Sorting), processing speed (Pattern Matching), vocabulary (Picture Naming), and mental flexibility (Card Sort; see Table 3 for means and SDs).

Table 3. Cognitive measures. Non-verbal IQ was assessed using the Wechsler abbreviated scale of intelligence and all other measures were obtained with the cognitive battery of the NIH toolbox.

	Mean	SD
Non-verbal IQ (WASI)	98.47	27.51
Working memory (List sorting)	102.43	13.96
Inhibitory control (Flanker)	112.43	7.92
Processing speed (Pattern matching)	111.41	20.08
Mental flexibility (Card sort)	105.80	10.87
Vocabulary (Picture naming)	113.88	14.12

As no generalized linear mixed-effects model would converge following the inclusion of cognitive measures, RT was entered as the outcome variable in a linear mixed-effects model with fixed effects of each of the cognitive measures (mean-centered), Competition, Language, and all two- and three-way interactions with competition and language. Random effects included random intercepts for Subject and Item, as well as by-subject random slopes for Competition and Language.

There was a nearly significant main effect of working memory in the short preview window (*Estimate* = –5.15, *SE* = 2.38, t = –2.17, p = .051), such that higher working memory was associated with faster response times (see Figure 4A; all other $p > .05$). As in earlier analyses, we observed a significant interaction between competition and language in the long preview window (*Estimate* = 58.64, *SE* = 16.91, t = 3.47, $p < .0001$), which was significantly qualified by working memory (*Estimate* = 4.53, *SE*= 1.04, t = 4.35, $p < .0001$; Figure 4B), inhibitory control (*Estimate* = –13.46, *SE* = 2.23, t = –6.64, $p < .0001$), and vocabulary (*Estimate* = 2.45, *SE* = 0.88, t = 2.79, p = .005).[1]

Working memory. Follow-up tests on the three-way interaction between language, competition, and working memory revealed that higher working memory was associated with significantly greater Spanish competition (*Estimate* = 3.99, *SE* = 1.23, t = 3.24, p = .007), but not English competition (*Estimate* = –0.53, *SE* = 1.12, t = –0.47, $p > .9$) (see Figure 4B).

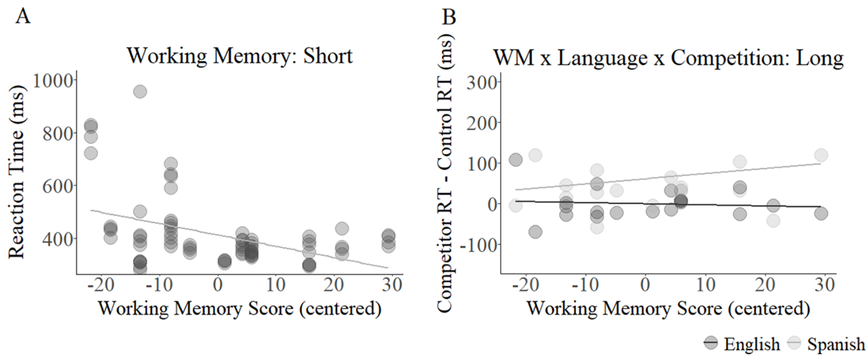

Figure 4. Relationship between working memory and (A) reaction time (ms) in the short preview window, and (B) the effects of language (English: dark gray; Spanish: light gray) on phonological competition (Competitor RT – Control RT), with higher scores on the Y-axis representing greater competition. Measures of working memory were mean centered, with higher scores on the X-axis representing superior performance.

Inhibitory control. Follow-up tests on the three-way interaction between language, competition, and inhibitory control revealed that greater inhibitory control was associated with significantly less Spanish competition (*Estimate* = –11.79, *SE* = 2.43, t = –4.85, $p < .001$), but not English competition (*Estimate* = 1.67, *SE* = 2.25, t = 0.74, p = .936) (Figure 5A).

English vocabulary. Lastly, though the lower order simple effects did not reach significance, follow-up tests on the interaction between language, competition, and English vocabulary revealed that better English vocabulary was associated with greater Spanish competition (*Estimate* = –1.61, *SE* = 1.08, t = –1.50, p = .151), and reduced English competition (*Estimate* = 0.84, *SE* = 1.01, t = 0.83, p = .419) (Figure 5B).

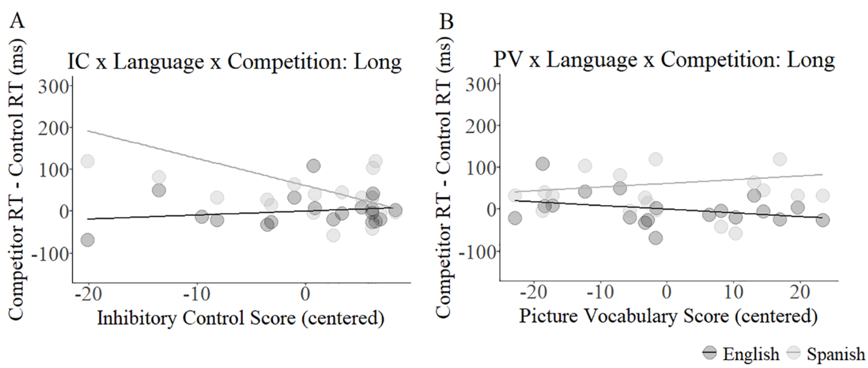

Figure 5. Relationship between phonological competition (Competitor RT – Control RT), language (English: dark gray; Spanish: light gray), and (A) inhibitory control or (B) English vocabulary (picture naming) in the long preview window. Higher scores on the Y-axis represent greater competition. Measures of inhibitory control and picture vocabulary were mean centered, with higher scores on the X-axis representing superior performance.

Discussion

Language is processed automatically, and it has far reaching consequences for experiences ranging from what we see to how we feel. This is true in cases when we actively seek to comprehend, as well as when we would rather not listen. Here, we demonstrate that in some cases, a less proficient language can be more distracting than a native tongue. Participants took significantly longer to identify a visual target when an irrelevant auditory stimulus shared phonological properties with the label of the visual distractor. Critically, this effect was only present when participants utilized their less proficient language, and the effect of language became increasingly pronounced with lower levels of proficiency in the non-dominant language. Note that the effect of phonological competition was only observed when participants were given sufficient time to process the phonological features of the labels associated with the visual objects (i.e. in the long preview condition). Notably, while no main effect of competition or interaction with language was found in the short preview condition, there was still a main effect of language with participants responding slower when the irrelevant auditory stimulus was in a less proficient tongue (recall that the amount of time participants had to process the auditory word did not vary across preview conditions). Together, these findings suggest that there may be multiple stages at which a less proficient language results in greater interference, both before and after phonological features of the visual objects have become activated. In other words, hearing a less proficient language captured more attention than a more proficient language regardless of whether the visual object labels were activated, but with sufficient time, greater attention snowballed into greater phonological interference.

At first glance, the notion that less proficient languages can be most distracting seems at odds with the findings that dominant languages cause more interference during Stroop tasks (e.g. Chen & Ho, 1986; Mägiste, 1984). This inconsistency may be resolved, however, by accounting for the primary task demands and the stage at which interference occurs. It may be that semantic activation is indeed harder to inhibit in a native tongue (as in the color Stroop task where words are automatically processed for meaning), particularly when the primary task involves language production and access to semantically similar words (e.g. saying "blue" while reading "red"). On the other hand, there may be greater initial exogenous capture of attention by a less proficient language. An analogy for this notion might be observed in the difference between emotional and color Stroop tasks. An emotional word like "murder" is likely to capture more attention than a simple color word like "blue." However, if asked to identify the color of a word (e.g. red), *blue* will cause greater interference than *murder* (Strauss et al., 2005). The amount of attention directed to each word thus depends on the stage and context of processing.

We initially proposed that less proficient languages may preferentially capture attention either due to their relative salience and novelty (e.g. Cavicchio et al., 2014), or else because of a compensatory mechanism for lower levels of proficiency (e.g. Costa & Santesteban, 2004). However, other processes may also be involved. For example, it may be the case that the cognitive load associated with listening to a less proficient language could disrupt participants' ability to ignore irrelevant speech. Tun et al. (2002) found that older adults were more distracted by irrelevant speech than younger adults when completing a unimodal auditory task, suggesting that cognitive resources are required for the suppression of distracting speech. While possible, we believe this explanation is less likely, as cognitive load should have been minimal in a task that required no production and discouraged comprehension. A potentially related factor to consider, however, is the extent to which the present findings are associated with baseline individual differences in cognitive control. Previous research suggests that bilinguals may excel at cognitive control tasks, likely due in part to their extensive practice managing interference across languages (Abutalebi & Green, 2008; Abutalebi et al., 2012). Indeed, our exploratory findings demonstrated that the degree of interference in the Spanish task was predicted by individual differences in inhibitory control. To the extent that individuals with higher Spanish proficiency were, in fact, more balanced bilinguals (with greater experience managing cross-linguistic interference), the present findings could potentially result from individual differences in executive function among those who are more bilingual, rather than higher Spanish proficiency per se. There are, however, three reasons to suspect that this is not the case, the first being that we found no evidence that Spanish proficiency was correlated with inhibitory control. Secondly, the amount of competition was not influenced by *relative* proficiency, as would be expected if more balanced bilinguals experienced less interference than less balanced bilinguals. Lastly, the effect of Spanish proficiency appeared to be specific to the Spanish trials; were it the case that Spanish proficiency indirectly captured more general differences in cognitive abilities, those with lower Spanish skills (i.e. less balanced bilinguals with lower cognitive control) should have experienced greater competition in English, as well as in Spanish.

One plausible alternative, or complementary explanation is that the observed effect results from greater spreading of phonological activation in less proficient languages. Weber and Cutler (2004) found that participants speaking their non-native language were more likely to consider distractors that shared loosely overlapping phonemes with a target (e.g. *panda* and *pencil*) relative to native speakers. This suggests that phonemic boundaries may be less constrained in less proficient languages. Phonologically overlapping words may therefore be perceived as more similar in a less proficient tongue, resulting in greater interference. Indeed, this explanation could help explain why we observed a different relationship between proficiency and interference compared to a similar study conducted by Singh and Mishra (2015). In their study, high and low-proficiency Hindi-English bilinguals completed a similar visual discrimination task with English auditory stimuli and found no effects of proficiency on phonological interference. However, our study differed from theirs in a number of critical ways, most notably that the spoken word in Singh and Mishra's (2015) paradigm directly named the competitor visual object ("apple" – picture of apple), whereas in our study, the spoken word was a phonological neighbor of the non-target visual object ("candy" – picture of a candle). The fact that we observe an effect of proficiency but they do not suggests that our effect may be due to greater spreading of phonological activation within the less proficient language. Note that this explanation is not mutually exclusive with the attentional salience account. Rather, it speaks to a potential downstream process that may occur once attention is captured.

Language processing is an on-going dance between activation, de-activation, and inhibition, which is made even more intricate by the presence of more than one language. While learning to juggle multiple languages, each linguistic system may become infused with specific characteristics that allow for their successful coordination. Indeed, this constant coordination has been shown to result in differences between monolinguals and bilinguals in cognitive abilities such as executive function (e.g. Bialystok, 2001; Costa et al., 2008). Furthermore, Mishra and colleagues (2012) demonstrated that bilinguals with high-proficiency were more efficient at disengaging from uninformative cues than those with low-proficiency, indicating that the impact of language experience on cognitive function can vary across bilinguals. This notion is consistent with Green and Abutalebi's Adaptive Control Hypothesis (2013), which posits that bilingual language control is supported by several dissociable cognitive functions, including conflict monitoring, salient cue detection, and inhibitory control – each of which can be independently influenced by bilingualism depending on the nature of the bilingual experience (e.g. habitual communication in dual- versus single-language contexts). Here, we propose that cognitive function may further depend on the nature of experience with particular languages. Tzelgov et al. (1990) theorized that with greater experience comes both increased activation of a language, as well as the ability to constrain it. In other words, we may be more practiced at inhibiting our dominant tongue (Bartolotti & Marian, 2012). On the other hand, the need for greater concentration when processing a less familiar language may lower the threshold for activation, making it easier to capture our attention. As a result of dynamic interactions between cognitive functions and linguistic abilities, the same bilingual may be more or less capable of inhibiting irrelevant linguistic cues depending on their level of expertise in that language.

To conclude, we observe that a less proficient language can cause greater phonological interference than a more proficient language when engaged in a non-linguistic task. While perhaps counterintuitive, this pattern may be understood by considering both the amount of practice that individuals have controlling each language, as well as the relative salience of words that are encountered more or less frequently. Whether it is due to greater inhibition of a native language or more attentional capture by a less familiar tongue during a non-linguistic task, we demonstrate that in some cases, a weaker language can be harder to ignore.

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Supplemental material

Supplemental material for this article is available online.

Note

1. Note that applying a log-transformation to the RT data does not affect the significance of results in the long preview window. The marginal effect of working memory in the short preview window, however, is no longer significant following log-transformation (p = .239). Similarly, reducing variance by replacing RTs exceeding the group mean + 2.5 standard deviations with the maximum RT within each condition results in largely the same pattern of results in the long preview window (including a significant Competition × Language interaction, as well as Competition × Language × Inhibitory Control and Competition × Language × Working Memory interactions). The Competition × Language x Vocabulary interaction, however, becomes nonsignificant, as does the marginal effect of working memory in the short preview condition.

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