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Noise modulates crosslinguistic effects on L2 auditory word recognition

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Abstract:	Purpose: The current study investigates whether crosslinguistic effects on auditory word recognition are modulated by the quality of the auditory signal (clear, noisy). Methods: In an online experiment, a group of Spanish-English bilingual listeners performed an auditory lexical decision task, in their second language (L2), English. words and pseudowords were either presented in the clear or were embedded in white auditory noise. Target words were varied in the degree to which they overlapped in their phonological form with their translation equivalents and were categorized as overlapping in form and meaning (cognates) or only in meaning (non-cognates). In order to test for effects of crosslinguistic competition, the phonological neighborhood density of the targets' translations was also manipulated. Results: The results show that crosslinguistic effects are impacted by noise; when the translation had a high neighborhood density, performance was worse for cognates than for non-cognates, especially in noise. Conclusions: The findings suggest that noise increases lexical competition across languages, as it does within a language, and that the crosslinguistic phonological overlap for cognates compared to non-cognates can further increase the pool by co-activating crosslinguistic lexical competitors. The results are discussed within the context of the bilingual word recognition literature and models of language and bilingual lexical processing.
Response to Reviewers:	Dear Editor: Thank you for the opportunity to revise our manuscript JSLHR-22-00368 entitled "Noise modulates crosslinguistic effects on L2 auditory word recognition". We thank the reviewers for their thoughtful comments. We believe we have addressed each of the reviewer comments, improving the quality manuscript. Point-by-point responses are provided in italics in the reviewer response letter. Importantly, we have expanded both the introduction and discussion and have included subheadings in each section to help organize separate concepts for the readers. Sincerely, Sara Guediche, Ph.D. Postdoctoral Researcher University of Connecticut sara.guediche@uconn.edu

Noise modulates crosslinguistic effects on L2 auditory word recognition

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Sara Guediche: Conceptualization, Experimental Design, Stimulus Creation, Interpretation of Results, Manuscript Preparation and Writing, Supervision

Eugenia Navarra: Experimental Design, Stimulus Creation, Running Participants, Data Analysis, Manuscript preparation

Clara Martin: Conceptualization, Experimental Design, Interpretation of Results, Manuscript Preparation, Funding, Supervision

Abstract

Purpose: The current study investigates whether crosslinguistic effects on auditory word recognition are modulated by the quality of the auditory signal (clear, noisy).

Methods: In an online experiment, a group of Spanish-English bilingual listeners performed an auditory lexical decision task, in their second language (L2), English. Words and pseudowords were either presented in the clear or were embedded in white auditory noise. Target words were varied in the degree to which they overlapped in their phonological form with their translation equivalents and were categorized according to their overlap as cognates (form and meaning) or non-cognates (meaning only). In order to test for effects of crosslinguistic competition, the phonological neighborhood density of the targets' translations was also manipulated.

Results: The results show that crosslinguistic effects are impacted by noise; when the translation had a high neighborhood density, performance was worse for cognates than for non-cognates, especially in noise.

Conclusions: The findings suggest that noise increases lexical competition across languages, as it does within a language, and that the crosslinguistic phonological overlap for cognates compared to non-cognates can further increase the pool of competitors by co-activating crosslinguistic lexical candidates. The results are discussed within the context of the bilingual word recognition literature and models of language and bilingual lexical processing.

Bilinguals often communicate with one another through spoken interactions in a non-native, second language (L2). These interactions commonly occur in noisy listening environments that compromise the quality of the speech signal and challenge comprehension (e.g., train station, cafeteria, etc.). Unfortunately, such adverse listening conditions have an even greater detrimental effect on the comprehension of a bilingual's L2 than L1 (Lecumberri et al., 2010; Mayo et al., 1997; Meador et al., 2000; Shi, 2010; Tabri et al., 2015). At the same time, L2 lexical processing is influenced by the bilingual's native language (L1) (Blumenfeld & Marian, 2013; Kroll et al., 2012, 2013; Marian et al., 2003; Van Hell and Dijkstra 2002; Van Hell & Tanner 2012). For example, L2 spoken word recognition performance is affected by overlap in orthography, phonology, and/or meaning with L1 words. These crosslinguistic effects likely contribute to the relative disadvantage experienced by L2 listeners in adverse listening conditions (Chen & Marian, 2016). This L2 noise disadvantage has not been found for non-linguistic stimuli, which suggests that general perceptual mechanisms are unaffected (Krizman et al., 2017). Yet, to date, there is little empirical work that addresses how the potential interactions between noise and crosslinguistic effects influence L2 word recognition (though see Guediche et al., 2020; 2021; Navarra-Barindelli, 2022). The goal of the present experiment is to investigate interactions between effects of crosslinguistic phonological and semantic overlap and effects of noise and their influence L2 auditory lexical decisions, in bilingual Spanish-English (L1/L2) listeners.

Contrasting effects of crosslinguistic lexical overlap

Depending on the nature of the overlap, crosslinguistic lexical interactions can either facilitate or hinder L2 word recognition. For example, overlap in lexical form for words that do not share meaning (homographs/homophones) across languages, such as 'carpet' in English and 'carpeta' in Spanish (translation 'folder') hinders bilingual word recognition performance across different tasks, including auditory lexical decision tasks (Lagrou et al., 2011; Schulpen et al., 2003). In contrast, overlap in lexical form for words that do share meaning (cognates), across languages, such as ‘paper’ (‘papel’ in Spanish) tends to improve recognition performance relative to words that share meaning and not form (non-cognates) such as ‘book’ (‘libro’ in Spanish) (e.g, Dijkstra & van Heuven, 1998; Dijkstra et al., 1999). The facilitation effects have been mainly reported for overlap in orthographic form (but see Bowers et al., 2000; Gollan et al, 1997; Pae 2020 for phonological overlap effects in cross-script bilinguals), in different types of paradigms including naming and lexical decision tasks.

Influential models of spoken word recognition such as the Bilingual Model of Lexical Access (BIMOLA) (Lewy & Grosjean, 1997) and the Bilingual Language Interaction Network for Comprehension of Speech (BLINCS) (Shook & Marian, 2013) predict the observed contrasting effects of lexical-semantic overlap. On one hand, interactions between semantically incongruent phonologically similar lexical forms compete with one another; this competition (depicted through lateral lexical-lexical inhibitory connections) leads to poorer recognition of homophones. On the other hand, interactions between semantically congruent lexical forms reinforce one another across hierarchical lexical and semantic levels (depicted through excitatory connections) and leads to cognate facilitation effects. The potential for both inhibitory and excitatory interactions (due to crosslinguistic phonological overlap) is what motivated the questions addressed by this study.

As an aside, however, we note that whereas *inhibitory* effects of homophones have been reported in countless studies on bilingual *auditory* word recognition (e.g, Lagrou et al., 2011; Marian et al., 2003), cognate effects have only been investigated in a few published studies conducted in the *auditory* modality (Cornut et al., 2021; Frances et al., 2021; Fricke, 2022; Guediche et al., 2020; 2021). In fact, reports of cognate *facilitation* seem to be mostly for *visual* word recognition (Caramazza & Brones, 1979; Cristoffanini et al., 1986; de Groot & Nas, 1991; Dijkstra et al., 1999; Dijkstra & van Heuven, 1998; Dufour & Kroll, 1995; Sanchez-Casas et al., 1992; Schwartz et al., 2007; Voga et al., 2007). We will return to this point later in the discussion.

<u>What happens with noise?</u>

A recent auditory word recognition study showed that inhibitory effects of cognate status (rather than the typically cited facilitation effects) can emerge, under noisy listening conditions (Guediche et al., 2020); specifically, the study showed that cognate status hindered auditory lexical decisions, in noise (speech babble) when preceded by a semantically unrelated prime. The authors speculated that under these semantically incongruent noisy conditions (that promote lexical competition), cognates were more vulnerable to crosslinguistic lexical competition than non-cognates due to an increased pool of similar-sounding L1 lexical candidates (phono-lexical competitors) being co-activated by the L1 cognate translation. In other words, akin to monolingual phonological neighborhood competition effects (Ziegler et al., 2003), the phono-lexical form of L1 cognate translations (e.g, ‘ruta’ (route)) is co-activated (Spivey & Marian, 1999), and in turn activates other similar-sounding words (competitors) in the L1 (e.g, ‘rata’ (rat)) that compete for selection with the L2 target. In contrast, the overall activation of non-cognate translations (e.g, ‘libro’ (book)) may be lower compared to cognates, any potentially co-activated phonological competitors of the L1 translation (e.g., “litro” (litre)) and would be more phonologically dissimilar from the L2 target (book), resulting in less competition. If this is the case, then the number of the L1 translation’s phonological competitors should have a relatively greater impact on the recognition performance of L2 cognates than non-cognates, especially in noise which increases lexical uncertainty (Taler et al., 2010; Zhang and Samuel, 2018). To directly probe these potential interactions, we manipulate 1) listening condition (clear, white noise), 2) cognate status (cognates, non-cognates), and 3) the phonological neighborhood density of the L1 translation (High, Low $\text{PhonND}_{\text{trans}}$: density of L1 words differing by one phoneme from the L1 translation), while controlling for the phonological neighborhood density of the L2 targets.

Experiment Predictions

There is little existing empirical evidence for the influence of noise on crosslinguistic effects, however, we turn to the above-mentioned functional architecture of interactive models of bilingual lexical access for insight. First, in clear listening conditions, we expect the previously reported cognate *facilitation* effect, predicted by models of spoken word recognition (Grosjean, 1997; Lewy & Grosjean, 2008; Shook and Marian, 2013) and found in visual word recognition studies. Based on the premise that cognate status increases the co-activation of L1 translations equivalents (Shook and Marian; 2013), similar-sounding L1 phonological neighbors should also make cognates more vulnerable to crosslinguistic competition. Therefore, cognates should show a relative disadvantage when the L1 translations have more dense phonological neighborhoods (i.e., the negative effect of a high phonological density should be greater for cognates than non-cognates). Second, interactive models predict exacerbating effects of noise on lexical competition, which has been found in monolingual listeners (Taler et al., 2010). Therefore, we also predict that the listening condition will modulate the interaction between cognate status and phonological neighborhood density. In other words, we expect the relative impact of a large neighborhood density on cognates to be larger in noisy than clear conditions, which would produce a cognate x phonological neighborhood density x noise interaction effect. Here, we employ white noise (SNR -3dB[1]), a common source of acoustic interference that has not yet been applied to investigations of crosslinguistic effects on L2 word recognition.

Implications

Characterizing the nature of crosslinguistic effects, as a function of listening conditions, will shed light on some of the more nuanced yet common listening challenges L2 listeners face daily. The findings will help advance theoretical models of bilingual spoken word recognition by specifying a more detailed functional architecture that takes into account more natural listening conditions. By elucidating the mechanisms that allow L2 listeners to flexibly perceive a variable or degraded speech input, better strategies for facilitating the L2 listening experience in more naturalistic listening conditions can be developed.

Methods

Participants

Participants were 44 Spanish-English bilinguals with at least an intermediate level of proficiency in their second language (English –L2). Participants were recruited in Madrid to avoid the incidence of a second L1 (such as Basque or Catalan) which is common in other regions of Spain. Participants' language proficiency was assessed using BEST –a picture naming task consisting of naming 65 common objects in Spanish and English (de Bruin et al., 2017). The selected participants had an English BEST score of 40 or above. Table 1 provides more detailed information about the participant profile. Participants had no history of

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[1] Many previous examining L2 word recognition under adverse listening conditions use either white noise or speech babble. We opted for white noise over speech babble in the current study so that there were no other potential confounding phonological competition effects arising from the noise content as might occur with babble. We chose an SNR of -3dB based on a pilot study in which 7 participants were tested on a subset of stimuli at different levels of noise including -3 dB, -5 dBs, -7 dB and a clear signal. We aimed for an SNR that resulted in a performance level of 70-80 % accuracy (as in Guediche et al., 2020), so as not to produce ceiling or floor effects. Thus, we selected the SNR level of -3dB, which yielded an average accuracy of 79%, across participants in the pilot experiment.

reading, hearing, speech, or psychiatric disorders. All participants provided informed consent before taking part in the experiment. Participants conducted the experiment online, in accordance with the Declaration of Helsinki and approved by the Basque Center on Cognition, Brain and Language Ethics Committee. Participants were paid for their participation.

[Table 1]

Stimuli

Stimulus Selection. A total number of target words was 450, half of which were cognates and the other half were non-cognates were selected. It was not possible to balance the full stimulus set across the two experimental factors of interest while controlling for confounding effects of lexical frequency and phonological neighborhood density. Therefore, two subsets of stimuli consisting of 384 words each (from the total 450) were used in two separate analysis designs[2] (for full stimulus lists see Supplementary Materials, Appendix A):

1) Across one subset of 384 stimuli, in one analysis design, the factors Listening Condition (clear vs. noise) × Cognate Status (cognates vs. non-cognates) × PhonoND$_{trans}$[3] (high vs. low phonological neighborhood density for the L1

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[2] All words were matched on the following characteristics: Number of letters, number of phonemes, number of syllables, number of orthographic neighbors in English, and the number of phonological neighbors in English (L2; language of the task) (CLEARPOND database; Marian et al., 2012; EsPal database: Duchon et al., 2013). Phonological cognates rate was the measure we used to define phonological overlap across translation equivalents; words were transcribed into the International Phonetic Alphabet (IPA), and the measure of overlap used was Levenshtein distance, corrected for length (Yujian & Bo, 2007). Cognates and non-cognates were defined by median split (see Tables 2 and 3 for average values). The phonological cognate rate was matched across high and low L2 frequency items and high and low L1 PhonoNDtrans items for cognates (p = .28 and p = .69, respectively) and for non-cognates (p = .37 and p = .29, respectively). Pseudowords were created using the Wuggy software program (Keuleers & Brysbaert, 2010) and were matched to words in length, number of syllables and number of phonemes. To create each pseudoword, 2 phonemes were changed for each word set.

[3] PhonoND$_{trans}$ = Phonological neighborhood density (translation), which reflects the density of the L1 translation’s phonological neighbors. For example, the translation of the word ‘pen’ is ‘bolígrafo’ and so includes ‘polígrafo’ as one of its neighbors; words with a low neighborhood were defined as those with 0-3 phonological neighbors whereas words with a high neighborhood were defined as those with > 4 phonological

translations) were manipulated, controlling for L2 phonological neighborhood density and L2 word frequency across conditions (PhonoND design). For this PhonoND design, cognate and non-cognate stimuli were further subdivided into half that had translation equivalents in L1 with low number of neighbors and the other half had translation equivalents in L1 with a high number of neighbors, based on a median split.

2) Across another subset of 384 stimuli, for another analysis design, the following factors Listening Condition (clear vs. noise) × Cognate Status (cognates vs. non-cognates) × L2 word frequency[4] (high vs. low) were manipulated, controlling for L1 and L2 phonological neighborhood density across conditions (Frequency design). For this Frequency design, cognate and non-cognate stimuli were further subdivided into half that had low frequency and half with high frequency and half[5], based on a median split, yielding a total of 96 words per condition for each design; the main purpose of this second subset including L2 word frequency was to ensure the persistence of frequency effects in noise—serving as a sanity check that differences in lexical access (Savin 1963; van Engen et al., 2020), across conditions, cannot be attributed to overall floor effects, in noise. The results of this analysis are presented in the results section, however since frequency effects persisted across all conditions, we do not discuss these findings.

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neighbors (range 4-76 neighbors; see Table 2 for average values). The neighborhood densities were matched across cognates and non-cognates.

[4] Words with low frequency had a range from 0.24 to 16.49 frequency per million, and words with high frequency had a range from 16.65 to 354.25 frequency per million (see Table 3 for average values). Frequency was matched across cognates and non-cognates.

[5] words with low frequency had a range from 0.24 to 16.49 frequency per million, and words with high frequency had a range from 16.65 to 354.25 frequency per million (see Table 3 for average values). Frequency was matched across cognates and non-cognates.

Across both designs, half of the items in each condition were presented in a clear auditory context, and the other half were presented in a noisy auditory context (see Stimulus Creation section). Stimuli from Clear and Noisy conditions were counterbalanced across participants.

[Table 2]

[Table 3]

Stimulus Creation. Auditory stimuli were recorded at a frequency of 44.1 kHz and 32 bits, in a soundproof room by a native speaker of English with a general American accent. Auditory files were normalized for amplitude. Stimuli were mixed with white auditory noise at a signal-to-noise ratio of -3 dB, using Praat (Boersma & Weenink, 2007). We added 50 ms of white noise to the beginning and end of each sound file. Using Goldwave, we applied a linear ramp-up to the preceding 50 ms of noise and ramp-down to the following 50 ms of noise (Craig, 1996).

Procedure

Participants performed a lexical decision task in their L2. The experiment was programmed using version 3.3.3 of OpenSesame (Mathôt et al., 2012) and was ran using the online JATOS platform (Lange et al., 2015). Before the experiment began, participants read written instructions in English explaining that they would have to decide whether the presented auditory stimulus was a word in English or not. Participants were asked to respond as quickly and accurately as possible.

Participants saw a fixation cross (‘+’) in the center of the screen for 500 ms and then they heard the auditory stimulus and were asked to make a lexical decision. They had a maximum of 2500 ms to respond to the auditory stimuli, starting from the onset of the word and responded using the F key on the keyboard for targets they deemed to be words and the J key for targets they deemed to be pseudowords. The experiment had four self-paced breaks. Prior to the start of the experiment, participants were presented with a practice block of four trials that did not contain any stimulus that were included in the actual experiment. The total duration of the experiment was approximately 60 minutes.

Data analyses

Accuracy and reaction times (RTs) measured from the onset of the stimulus were submitted to 2 × 2 × 2 repeated measures analysis of variance (ANOVA): In the PhonoND design, we included the factors listening condition (clear vs. noise), cognate status (cognates vs. non-cognates), and PhonoND$_{trans}$ in L1 (high vs. low). In the L2Freq design, we included the factors listening condition (clear vs. noise), cognate status (cognates vs. non-cognates), and L2 word frequency (high vs. low), controlling for L1 and L2 PhonoND$_{trans}$. All analyses were carried out in JASP (JASP Team, 2018).

Only word data were analyzed. For the accuracy analyses, null responses were removed (1.02% of data). Reaction time (RT) analyses on target words, were conducted on correct responses removing those that were 2.5 standard deviations above or below the mean for a given participant (2.58% of all trials across participants).

Results

We first present the results for the 2 x 2 x 2 listening condition (clear vs. noise) x PhonoND$_{trans}$ (high vs. low) x cognate status (cognates vs. non-cognates) ANOVA analysis with subject as a random factor for 1) accuracy and 2) reaction time as dependent measures. Item-analyses are presented in Appendix B of the Supplementary Materials. We then present results for the 2 x 2 x 2 listening condition (clear vs. noise) x Frequency (high vs. low) x cognate status (cognates vs. non-cognates) ANOVA analysis with subject as a random factor for 1) accuracy and 2) reaction time as dependent measures. Item-analyses are presented in Appendix B of the Supplementary Materials. For the by-item ANOVA, listening condition was a within-item factor.

Results for Phonological Neighborhood Density effects. Table 4 provides the accuracy scores for all conditions.

Accuracy. The results of the 2 x 2 x 2 listening condition (clear vs. noise) x PhonoND$_{\text{trans}}$ (high vs. low) x cognate status (cognates vs. non-cognates) ANOVA on accuracy shows a significant listening condition effect, $F_1(1, 43) = 125.317$, $p < .001$, $\eta_p^2 = .745$, showing higher accuracy for words presented in clear listening condition (Mean = .83, SD = .11) than in noise (Mean = .68, SD = .14). We found a main effect of cognate status, $F_1(1, 43) = 8.123$, $p = .007$, $\eta_p^2 = .159$; performance on cognates (Mean = .74, SD = .15) was worse than non-cognates (Mean = .76, SD = .14).

The main effect of PhonoND$_{\text{trans}}$ effect, $F_1(1, 43) = .039$, $p = .845$, $\eta_p^2 = .001$ was not significant but there was a significant interaction between PhonoND$_{\text{trans}}$, $F_1(1, 43) = 45.811$, $p < .001$, $\eta_p^2 = .516$. The post-hoc t-tests showed lower performance for cognates with a high number of phonological neighbors compared to low, $t(43) = -6.529$, $p_b < .001$, and no significant cognate effect for words with a low number of phonological neighbors, $t(43) = 2.156$, $p_b = .204$. This suggests that word recognition performance is susceptible to lexical competition effects from phonological neighbors of the translated target.

In addition, we found a 3-way interaction between listening condition, cognate status and PhonoND$_{\text{trans}}$, $F_1(1, 43) = 11.154$, $p = .002$, $\eta_p^2 = .206$ (see Figure 1) reflecting the differential effect of noise for cognate with a translation that has low compared to high phonological neighborhood densities. Post-hoc analyses show that, cognates with a high number of PhonoND$_{\text{trans}}$ were less accurate than noncognates, in clear $t(43) = -3.867$, $p_b = .004$ and in noise, $t(43) = -5.397$, $p_b < .001$. However, whereas performance on cognates with a low number of PhonoND$_{\text{trans}}$ did not significantly differ from non-cognates, in clear, *p > .05, it* was better $t(43) = 3.783$, $p_b = .006$, in noise. These findings suggest that cognate status only hinders performance when they activate many other lexical competitors.

[Figure 1]

No other effects or interactions were significant ($p > .05$). The by-item (F2) analyses are reported in Appendix B of the Supplementary Materials.

[Table 4]

<u>*Reaction Time*</u>. Table 5 provides the reaction time measures for all conditions. These findings are consistent with the accuracy data and thus ensure that the interaction did not simply emerge due to a speed/accuracy tradeoff. The results of the 2 x 2 x 2 listening condition (clear vs. noise) x PhonoND$_{\text{trans}}$ (high vs. low) x cognate status (cognates vs. non-cognates) ANOVA on reaction time show a significant effect of listening condition, F1(1, 43) = 315.722, $p < .001$, $\eta p^2 = .880$, with faster recognition of words presented in clear (Mean = 1010.71, SD = 110.50) than in noise (Mean = 1135.30, SD = 126.44). We found a main effect of PhonoND$_{\text{trans}}$, F1(1, 43) = 19.828, $p < .001$, ηp2 = .316, showing that responses for words with a low number of PhonoND$_{\text{trans}}$ were faster (Mean = 1063.89, SD = 134.37) than those with a high number of PhonoND$_{\text{trans}}$ (Mean = 1082.11, SD = 133.34). We did not find a main effect of cognate status, F1(1, 43) = 3.891, $p = .055$, $\eta p^2 = .083$. Again, these findings provide more evidence that L2 words are susceptible to crosslinguistic phono-lexical competition.

The 2-way interaction between cognate status and PhonoND$_{\text{trans}}$, $F_1(1, 43) = 25.579$, $p < .001$, $\eta_p^2 = .373$ was also significant, with slower performance for cognates with a high number of $\text{PhonoND}_{\text{trans}}$ than non-cognates, $t(43) = 5.016$, $p_b < .001$. There was no significant effect of cognate status for words with low $\text{PhonoND}_{\text{trans}}$, $t(43) = -2.285$, $p_b = .149$.

No other effects or interactions were significant ($p > .05$). The by-item (F2) analyses are reported in Appendix B of the Supplementary Materials.

[Table 5]

Additional ANCOVA Analysis. To test for potential effects of crosslinguistic orthographic overlap on our observed results, we conducted an ANCOVA analysis on the PhonoND design with listening condition as a within-item factor, phonological neighborhood and cognate status as between-item factors, and orthographic rate as a covariate, separately, on RTs and accuracy as dependent measures. Orthographic cognate rate was calculated using the Levenshtein distance measure corrected for length (Yujian &B, 2007).[6]

Results for Frequency effects. In this subsection we will present the results of the 2 x 2 x 2 listening condition (clear vs. noise) × word frequency (high vs. low) × cognate status (cognates vs. non-cognates) ANOVA analysis. For the F1 analyses, all factors (listening condition, frequency and cognate status) were introduced as a within-subject factors. For the F2 analyses, the listening condition was introduced as a within-item factor, while frequency and cognate status were introduced as between-item factors.

Accuracy Results. Table 6 provides the accuracy scores for all conditions. The results for the 2 x 2 x 2 listening condition (clear vs. noise) x Frequency (high vs. low) x cognate status (cognates vs. non-cognates) ANOVA analysis on accuracy show a main effect of listening

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[6] For RTs we found a significant effect of orthographic rate effect $F(1, 376) = 11.278$, $p < .001$; $n_p^2 = .029$, but no interaction between cognate status and orthographic rate, $F(1, 376) = 1.576$, $p = .210$, $n_p^2 = .004$. For accuracy we found a significant main effect of orthographic rate effect, $F(1, 376) = 8.480$, $p = .004$, $n_p^2 = .022$ but no interaction between cognate status and orthographic rate $F(1, 376) = .715$; $p = .398$, $n_p^2 = .002$.

condition, $F_1(1, 43) = 109.172$, $p < .001$, $\eta_p^2 = .717$, with higher accuracy for words presented in clear (Mean = .83, SD = .14) than in noise (Mean = .67, SD = .15). We also found a frequency effect, $F_1(1, 43) = 161.523$, $p < .001$, $\eta_p^2 = .790$, with higher accuracy for high frequency words (Mean = .82, SD = .14) as compared to low frequency words (Mean = .68, SD = .16). We did not find a significant effect of cognate status, $F_1(1, 43) = 0.808$, $p = .374$, $\eta_p^2 = .018$.

There was a significant 2-way interaction between listening conditions and cognate status, $F_1(1, 43) = 7.725$, $p = .008$, $\eta_p^2 = .152$. The post-hoc t-tests shows trending higher accuracy for non-cognates compared to cognates, in clear listening conditions, $t(43) = -2.612$, $p_b = .064$, and no significant difference between cognates and non-cognates in noise.

We found an interaction between cognate status and frequency, $F_1(1, 43) = 22.836$, $p < .001$, $\eta_p^2 = .347$. Post-hoc t-tests showed a significant frequency effect for cognates, $t\ (43) = 13.451$, $pb < .001$, and for non-cognates, $t = 8.896$, $pb < .001$. The magnitude of the frequency effect was larger for cognates (mean low frequency = .661, mean high frequency = .834) than for non-cognates (mean low frequency = .697, mean high frequency = .811).

We also found a 3-way interaction between listening conditions, frequency and cognate status, $F_1(1, 43) = 4.653$, $p = .037$, $\eta_p^2 = .098$. Post-hoc t-tests showed an lower accuracy for cognate with low frequency in clear listening condition, $t(43) = -5.502$, $p_b < .001$, and no effect for high frequency words in clear listening conditions, $t(43) = 1.195$, $p_b = 1$. In noise, we found no effects of cognate status in either of the frequency conditions, $p > .05$. Frequency effects were significant in all cognate conditions, across both listening conditions: cognate words in clear listening conditions, $t = 11.789$, $pb < .001$, non-cognate words in the clear, $t = 6.594$, $pb < .001$, cognate words in noise, $t = 9.962$, $pb < .001$, and non-cognates in noise, $t = 7.793$, $pb < .001$. The magnitude of the frequency effect in the clear was larger for cognates (mean low frequency = .721, mean high frequency = .908) than for non-cognates (mean low frequency = .788, mean high frequency = .893). In noise, the magnitude of the frequency effect was similar for both cognates (mean low frequency = .601, mean high frequency = .760) and non-cognates (mean low frequency = .605, mean high frequency = .729). The by-item (F2) analyses are reported in Appendix C of the Supplementary Materials.

[Table 6]

Reaction Time Results. Table 7 provides the reaction times measures for all conditions. The results for the 2 x 2 x 2 listening condition (clear vs. noise) x Frequency (high vs. low) x cognate status (cognates vs. non-cognates) ANOVA analysis on reaction time show a significant main effect of listening condition, $F_1(1, 43) = 321.229$, $p < .001$, $\eta_p^2 = .882$ showing faster responses for words presented in clear (Mean = 1015.07, SD = 118.59) than in noise (Mean = 1142.08, SD = 126.58). We found a frequency effect, $F_1(1, 43) = 186.444$, $p < .001$, $\eta_p^2 = .813$, showing a faster response for high frequency words (Mean = 1045.07, SD = 129.59) as compared to low frequency words (Mean = 1112.08, SD = 138.38). We did not find a significant effect of cognate status, $F_1(1, 43) = 0.444$, $p = .509$, $\eta_p^2 = .010$.

We found an interaction between cognate status and frequency, $F_1(1, 43) = 11.964$, $p = .001$, $\eta_p^2 = .218$. The post-hoc t-tests showed an inhibitory cognate effect for low frequency words, $t(43) = 2.935$, $p_b = .026$, and no cognate effect for high frequency words, $t(43) = -2.000$, $p_b = .292$.

We found a 3-way interaction between listening condition, frequency and cognate status, $F_1(1, 43) = 8.580$, $p = .005$, $\eta_p^2 = .166$. In the clear listening condition, post-hoc t-tests showed an inhibitory cognate effect for low frequency words, $t(43) = 3.721$, $p_b = .008$, and no significant effect of cognate status for high frequency words in the clear, $t(43) = -2.395$, $p_b =$

.496. In noisy listening conditions, there was no significant effect of cognate status for either for the frequency conditions, $p > .05$.

No other effects or interactions were significant ($p > .05$). The by-item (F2) analyses are reported in Appendix C of the Supplementary Materials.

[Table 7]

The results show no interactions between orthographic cognate rate and the other experimental factors of interest.[7]

Summary of Results. Overall, the results show the expected negative effect of noise on L2 auditory lexical decisions for both accuracy and reactions times. Surprisingly, we did not find an overall facilitation effect of cognate status. To address this unexpected finding, the discussion revisits the auditory literature on cognate effects. The interaction effects shed further light on these findings. Both accuracy and reaction time measures show the predicted interaction effect between Cognate Status and Phonological Neighborhood Density with cognates being more susceptible to negative effects of high L1 translation neighborhoods compared to non-cognates. This provides evidence for crosslinguistic phono-lexical competition. In addition, accuracy measures were sensitive to the three-way interaction between Listening Condition, Cognate Status, and Phonological Neighborhood Density such that the difference between the effect of low vs. high Phonological Neighborhood on cognates vs. non-cognates is exaggerated, in noisy listening conditions. A cognate facilitation effect emerged, only for items with low neighborhood densities, and only in noise. These somewhat unexpected findings can be accounted for within an interactive framework, as discussed below.

Discussion

L2 compared to L1 word recognition tends to be especially susceptible to listening conditions that degrade the quality of the speech signal (Lecumberri et al., 2010; Shi., 2010; Tabri et al., 2015), such as noise. At the same time, it is also influenced by crosslinguistic interactions. The goal of the current experiment was to investigate potential modulatory effects of listening condition on crosslinguistic effects, and to better characterize the nature of crosslinguistic phono-lexical-semantic interactions and their impact on L2 auditory lexical decisions. To this end, Spanish-English (L1/L2) bilinguals performed a lexical decision task in which 1) listening condition (clear vs noisy), 2) phonological cognate status of L2 target words, and 3) the phonological neighborhood density of their L1 translations (low vs. high) were manipulated.

Turning first to the main effects, we found the expected detrimental effect of noise on both lexical decision accuracy and reactions times, typically attributed to increased lexical competition (Brungart, 2001; Kalikow, 1977; Mattys et al. 2012; Scharenborg & van Os, 2019; Sorin & Thouin-Daniel, 1983). The cognate facilitation effect commonly reported across L2 *visual* word recognition studies did not emerge here (at least not in the typical clear listening conditions). Rather, as predicted, cognate status interacted with our experimental factors which we discuss below.

Cognate Effects

A closer look at the literature on bilingual lexical processing, which has alluded to similar cognate facilitation effects for auditory and visual modalities, reveals only a small number of published studies that even investigate cognate effects on *spoken* word recognition (Bultena et al. 2015; Frances et al. 2021; Fricke, 2022; Guediche et al., 2020, 2021). Other frequently referenced work remains unpublished (Hammer, 1975; Garrido, 2018;

Zwitserlood et al., 2007), looks at effects of other types of phono-lexical overlap (not specific to cognates) (Marian et al., 2003), or cites *visual* word recognition studies looking at phonological overlap (Dijkstra, 1999). Across the limited number of studies on L2 *auditory* word recognition, the cognate effects observed are actually mixed with a few cases showing null and inhibitory effects (e.g, Cornut et al. 2021; Frances et al., 2021), and with facilitation generally emerging in other tasks such as shadowing (rather than lexical decision) (e.g Hammer, 1975). Beyond the factors investigated in the current study, it is not clear if and/or why cognate effects might manifest differently across visual and auditory modalities (in past studies) though differences in task, definitions of cognate status, language proficiency, dependent measures, and language similarity (Bultena et al., 2015; Fricke 2022; Guediche et al., 2020; Hammer, 1975) all likely contribute to mixed findings.

There is ample evidence for non-selective language co-activation from auditory word recognition studies that employ other manipulations of phonological-lexical L1-L2 overlap (e.g, homophones) (Lagrou et al., 2011) and show effects on L2 lexical processing. However, because cognate facilitation effects have been taken as evidence for language co-activation, their absence is often used to argue for language-selective activation. Nevertheless, the findings from the current study suggest that this is not the case, here; crosslinguistic effects on L2 auditory word recognition emerge even when there is no cognate facilitation effect. The full set of results, in the current study, sheds light on previously unexplored factors that might alter the expression of cognate effects on L2 auditory lexical decisions, and is not consistent with language-selective activation.

Cognate Status and Phonological Neighborhood density interaction

Turning to the predicted interactions of interest: First, we found a two-way Cognate status x Phonological Neighborhood density interaction. According to interactive models of bilingual spoken word recognition like BLINCS (Shook & Marian, 2013), language co-activation results from both bottom-up feedforward processing of the auditory input, as well as top-down feedback from the semantic level. Consequently, cognate activation at the phono-lexical level gets a relative boost because it benefits both from shared phonological information that maps onto overlapping lexical forms (through bottom-up input), as well as the shared semantic information as it feeds back and converges onto the overlapping lexical forms (through top-down feedback) (Shook & Marian, 2013). Because L1 translation equivalents of cognates are, as a result, more strongly activated and are also represented closer to one another (compared to L1 translation equivalents of non-cognates), so will be their phonological neighbors. Consequently, such an architecture predicts that L1 phonological neighbors of the L1 translation will potentially compete with L2 Cognates, giving rise to an interaction between Cognate Status and Phonological neighborhood density of L1 translation equivalents. Indeed, this is what we showed; in clear listening conditions, performance on L2 words was worse for cognates when the L1 translation had a high phonological neighborhood density. The same negative effect of a large $\mathrm{PhonND}_{\mathrm{trans}}$ for cognates compared to non-cognates was found for both accuracy and reaction times. This is consistent with prior work that shows effects of competition on both accuracy and reaction time measures (Karaminis et al., 2022).

Adding on Noise

We also found the predicted three-way interaction between Cognate Status, Phonological neighborhood density, and Listening Condition on accuracy; noise had a more detrimental effect on cognate targets with translations that had greater L1 neighborhood densities. Noise adds another dimension of complexity, in essence, exaggerating the negative effect of a large phonological neighborhood—just as it does for phonological neighborhood effects, in monolinguals (Taler et al., 2010). The finding is consistent with Guediche et al.'s (2020) study who attributed their observed inhibitory effects of cognate status following a semantically unrelated prime, in noise, to increased crosslinguistic competition. To briefly summarize their results and interpretation again, the study used a semantic priming paradigm and found that following an unrelated semantic prime, participants were less accurate in recognizing a noisy target when it was a cognate compared to a non-cognate. The authors suggested that enhanced crosslinguistic lexical competition (for cognate targets following unrelated primes, in noise) results from the co-activation of the phonological competitors of the L1 translation. Here, we provide corroborating evidence for this interpretation by showing enhanced crosslinguistic lexical competition (for cognates, in noise), when the phonological neighborhood density for the L1 translations is high.

Some evidence for cognate facilitation

Interestingly, when the phonological neighborhood density for the L1 translations was low, noisy conditions led to more accurate responses for cognates than non-cognates. So, although the classical cognate facilitation did not emerge in the clear, it did in noise for this condition. Why would this be the case?

A number of speech processing studies, in monolinguals, shows that noise affects feedforward-feedback interactions, weighting feedback more heavily when it is more reliable and predictive (e.g, Obleser et al. 2007). The poorer the quality of the signal, the more difficult it is to distinguish among similar-sounding candidates, and so the more word recognition must depend on feedback. Indeed, semantic priming which can provide a source of feedback has been shown to mitigate effects of crosslinguistic competition and reduce the burden of noise on cognitive demands (Guediche et al., 2020; Guediche et al., 2021). Consequently, in a bilingual system where semantic feedback inherently boosts the relative activation of a cognate’s lexical form (compared to a non-cognate), noisy conditions that promote reliance on feedback may benefit cognate recognition accuracy more than non-cognate recognition. However, because the cognate’s co-activated crosslinguistic phonological competitors will also get a boost (through lexical connections), the number of crosslinguistic competitors will also impact accuracy and thus facilitation is most likely when there are few competitors. In other words, when increased reliance on feedback due to noise is needed for accurate word recognition, it may provide a relative benefit to cognates as long as it is not overridden by the detrimental effect of a high number of crosslinguistic competitors.

Altogether, the results point to the fact that L2 lexical processing is influenced by environmental, lexical and crosslinguistic factors, all of which interact with one another. Essentially, in addition to the typical effects on auditory word recognition, found in monolinguals, bilinguals must also contend with crosslinguistic effects of a word’s overlapping phonology and/or meaning which influences both bottom-up and top-down processes. The simultaneous effects of noise on both feedforward and feedback processes, and how they propagate within and across languages, could lead to opposing effects on word recognition.

Considering the role of orthography

The complex interactions revealed by the results of the current experiment may explain why less bilingual auditory compared to visual words studies have focused their investigations on cognate effects. One additional factor, which we did not discuss, may also be of relevance to these results. A recently published study showed that L2 orthographic form overlap with L1 translations may hinder the ability to differentiate L2 words and pseudowords, in an auditory lexical decision task (Frances et al., 2021). In the current study, cognate status was based on the amount of overlapping phonological/phonetic form, however, orthographic overlap was unavoidable (and necessarily higher for the cognate condition to meet the criteria for the other experimental manipulations). The effects in Frances et al. (2021) were restricted to A' measures (no effects on lexical decision accuracy or reaction times); nevertheless, we still conducted an exploratory ANCOVA analysis to examine the potential effects of crosslinguistic orthographic overlap on our observed results. The results suggest that orthographic overlap does not appear to interact with any of our other experimental factors of interest. Other recent work also shows cognate effects that are present in the visual modality but absent in the auditory modality (Cornut et al., 2021). However, since effects of phonological and orthographic cognate rates were highly correlated in this study, the possibility of an orthographic component to our observed effects cannot be completely ruled out.

To further explore the role of orthography on cognate effects in auditory word recognition, future work could examine the nature of the interactions reported here, in cross-script bilinguals. In this way, effects of phonological overlap could be isolated from orthographic effects. To our knowledge, cross-script cognate effects have only been examined using visual paradigms. An interesting future direction is to investigate crosslinguistic effects as a function of bilingual language script similarity.

Study Limitations

There are many other factors that affect auditory word recognition that will need to be considered in future research on L2 word recognition. For example, not all phonological neighbors have the same detrimental effect. Many studies have shown differences in competition effects depending on position or proportion of overlap, in monolinguals (e.g, Allopenna et al., 1998; Karaminis et al., 2022 McQueen & Huettig, 2012; Radeau et al., 2015; Simmons & Magnuson, 2018). Marian et al. (2003) showed that position of overlap also matters for crosslinguistic influences, though few studies have examined the effect of overlap position on cognate effects (see Comeseña et al., 2018 for deviant letter position effects and Muntendam et al., 2022 for effects of stress position).

In general, it is important to keep in mind that the degree to which L1 influences L2 depends on interactions with noise or other acoustic manipulations such as accent (see Frances et al., 2022), and other factors known to affect lexical processing such as frequency and phonological neighborhood density among other linguistic properties (Dijkstra, 2003). These interactions may have clinical implications providing a way to tap into deficits in lexical retrieval, selection, and/or competition. Identifying such deficits would allow for the development of potential compensatory strategies that can overcome different challenges that arise under adverse listening conditions.

Supplementary Materials: Appendix A provides the list of stimuli. Appendix B is a table showing significant effect the F2 analysis of the PhonoND Design, Appendix C B is a table showing significant effect the F2 analysis of the L2Freq Design.

Data Availability statement:

The datasets for the current study are available on OSF,

https://osf.io/hdyuv/?view_only=01623287cb5c480aa72adc54df85d64b

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References

Allopenna, P. D., Magnuson, J. S., & Tanenhaus, M. K. (1998). Tracking the time course of spoken word recognition using eye movements: Evidence for continuous mapping models. *Journal of memory and languag*e, 38(4), 419-439.

Blumenfeld, H. K., & Marian, V. (2013). Parallel language activation and cognitive control during spoken word recognition in bilinguals. *Journal of Cognitive Psychology*, *25*(5). https://doi.org/10.1080/20445911.2013.812093

Boersma, P., & Weenink, D. (2007). Praat: doing phonetics by computer (Version 4.5.). Retrieved from http://www.praat.org/, 5(9/10).

Bowers, J.S., Mimouni, Z. & Arguin, M. (2000). Orthography plays a critical role in cognate priming: Evidence from French/English and Arabic/French cognates. *Memory & Cognition* 28, 1289–1296. https://doi.org/10.3758/BF03211829

Brungart, D. S. (2001). Informational and energetic masking effects in the perception of two simultaneous talkers. *The Journal of the Acoustical Society of America*, *109*(3). https://doi.org/10.1121/1.1345696

Bultena, S., Dijkstra, T., & van Hell, J. G. (2015). Switch cost modulations in bilingual sentence processing: evidence from shadowing. *Language, Cognition and Neuroscience*, *30*(5). https://doi.org/10.1080/23273798.2014.964268

Caramazza, A., & Brones, I. (1979). Lexical access in bilinguals. *Bulletin of the Psychonomic Society*, *13*(4). https://doi.org/10.3758/BF03335062

Chen, P., & Marian, V. (2016). Bilingual spoken word recognition. In Speech Perception and Spoken Word Recognition (pp. 153-173). *Psychology Press*.

Comesaña, M., Coelho, R., Oliveira, H., & Paula Soares, A. (2018). How letter order is encoded in bilingual reading? The role of deviant-letter position in cognate word recognition. *Speech, Language and Hearing, 21(2), 90-93.*

Cornut, C., Mahé, G., & Casalis, S. (2021). L2 word recognition in French–English late bilinguals: does modality matter?. *Bilingualism: Language and Cognition*, 1-16.

Craig, S. C. (1996). Goldwave, *Comprehensive Digital Computer Program.*

Cristoffanini, P., Kirsner, K., & Milech, D. (1986). Bilingual Lexical Representation: The Status of Spanish-English Cognates. *The Quarterly Journal of Experimental Psychology Section A*. https://doi.org/10.1080/14640748608401604

de Bruin, A., Carreiras, M., & Duñabeitia, J. A. (2017). The BEST dataset of language proficiency. *Frontiers in Psychology*. https://doi.org/10.3389/fpsyg.2017.00522

de Groot, A. M. B., & Nas, G. L. J. (1991). Lexical representation of cognates and noncognates in compound bilinguals. *Journal of Memory and Language*, *30*(1), 90-123. https://doi.org/10.1016/0749-596X(91)90012-9

Dijkstra, T. (2003). Lexical processing in bilinguals and multilinguals: The word selection problem. In *The multilingual lexicon (pp. 11-26). Springer, Dordrecht.*

Dijkstra, T., & van Heuven, W. J. B. (1998). The BIA model and bilingual word recognition. En *Localist connectionist approaches to human cognition*.

Dijkstra, Ton, Jonathan Grainger, and Walter JB Van Heuven. (1999). "Recognition of Cognates and Interlingual Homographs: The Neglected Role of Phonology." *Journal of Memory and Language* 41(4), 496–518.

Dijkstra, T., van Heuven, W. J. B., Jaarsveld, V., Ten, B., Gollan, Forster, & Frost. (1999). Foreign Language Knowledge and Native Language Performance. *Jared & Kroll Nas*, *9*(4), 780-789.

Duchon, A., Perea, M., Sebastián-Gallés, N., Martí, A., & Carreiras, M. (2013). EsPal: One-stop shopping for Spanish word properties. *Behavior Research Methods*, *45*(4).

https://doi.org/10.3758/s13428-013-0326-1

Dufour, R., & Kroll, J. F. (1995). Matching words to concepts in two languages: A test of the concept mediation model of bilingual representation. *Memory & Cognition*. https://doi.org/10.3758/BF03197219

Frances, C., Navarra-Barindelli, E., & Martin, C. D. (2021). Inhibitory and facilitatory effects of phonological and orthographic similarity on L2 word recognition across modalities in bilinguals. *Scientific Reports*, 11(1). https://doi.org/10.1038/s41598-021-92259-z

Frances, C., Navarra-Barindelli, E., & Martin, C. D. (2022). Speaker Accent Modulates the Effects of Orthographic and Phonological Similarity on Auditory Processing by Learners of English.

Fricke, M. (2022). Modulation of cross-language activation during bilingual auditory word recognition: Effects of language experience, but not competing background noise. *Frontiers in Psychology*, 96.

Garrido Pozú, J. J. (2018). Aural Processing of Cognates in Learners of Spanish as a Second Language.

Gollan, T. H., Forster, K. I., & Frost, R. (1997). Translation priming with different scripts: Masked priming with cognates and noncognates in Hebrew–English bilinguals. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 23(5), 1122.

Grosjean, F. (1997). The bilingual individual. *Interpreting*, *2*(1-2), 163-187.

Guediche, S., Baart, M., & Samuel, A. G. (2020). Semantic priming effects can be modulated by crosslinguistic interactions during second-language auditory word recognition. *Bilingualism*. https://doi.org/10.1017/S1366728920000164

Guediche, S., de Bruin, A., Caballero-Gaudes, C., Baart, M., & Samuel, A. G. (2021). Second- language word recognition in noise: Interdependent neuromodulatory effects of semantic context and crosslinguistic interactions driven by word form similarity. *NeuroImage*, 237, 118168.

Hammer, P. (1975). The role of English-French cognates in listening and reading comprehension in the learning of French as a second language

JASP Team. (2018). *JASP (Version 0.9)*.

Karaminis, T., Hintz, F., & Scharenborg, O. (2022). The Presence of Background Noise Extends the Competitor Space in Native and Non- Native Spoken- Word Recognition: Insights from Computational Modeling. *Cognitive Science*, 46(2), e13110."

Keuleers, E., & Brysbaert, M. (2010). Wuggy: A multilingual pseudoword generator. *Behavior Research Methods*. https://doi.org/10.3758/BRM.42.3.627

Krizman, J., Bradlow, A. R., Lam, S. S. Y., & Kraus, N. (2017). How bilinguals listen in noise: Linguistic and non-linguistic factors. *Bilingualism: Language and Cognition*, 20(4), 834-843.

Kroll, J. F., Dussias, P. E., Bogulski, C. A., & Kroff, J. R. V. (2012). Juggling two languages in one mind. What bilinguals tell us about language processing and its consequences for cognition. En *Psychology of Learning and Motivation - Advances in Research and Theory* (Vol. 56). https://doi.org/10.1016/B978-0-12-394393-4.00007-8

Kroll, J. F., Gullifer, J. W., & Rossi, E. (2013). The multilingual lexicon: The cognitive and neural basis of lexical comprehension and production in two or more languages. En *Annual Review of Applied Linguistics* (Vol. 33). https://doi.org/10.1017/S0267190513000111

Lagrou, E., Hartsuiker, R. J., & Duyck, W. (2011). Knowledge of a Second Language Influences Auditory Word Recognition in the Native Language. *Journal of Experimental Psychology: Learning Memory and Cognition*, *37*(4).

https://doi.org/10.1037/a0023217

Lange, K., Kühn, S., & Filevich, E. (2015). «Just another tool for online studies» (JATOS): An easy solution for setup and management of web servers supporting online studies. *PLoS ONE*, 10(6). https://doi.org/10.1371/journal.pone.0130834

Lecumberri, M. L. G., Cooke, M., & Cutler, A. (2010). Non-native speech perception in adverse conditions: A review. Speech communication, 52(11-12), 864-886.

Léwy, N., & Grosjean, F. (1997). A computational model of bilingual lexical access. Manuscript in preparation, Neuchâtel University, Neuchâtel, Switzerland.

Léwy, N. (2008). The Léwy and Grosjean BIMOLA model. *Studying bilinguals*, 201-210.

Marian, Viorica, Henrike K. Blumenfeld, and Olga V. Boukrina. "Sensitiviity to Phonological Similarity within and across Languages." Journal of Psycholinguistic Research 37, no. 3 (2008): 141–170. https://doi.org/10.10007/s10936-007-9064-9.

Marian, V., Bartolotti, J., Chabal, S., & Shook, A. (2012). Clearpond: Cross-linguistic easy-access resource for phonological and orthographic neighborhood densities. *PLoS ONE*. https://doi.org/10.1371/journal.pone.0043230

Mathôt, S., Schreij, D., & Theeuwes, J. (2012). OpenSesame: An open-source, graphical experiment builder for the social sciences. In *Behavior Research Methods* (Vol. 44, Número 2). https://doi.org/10.3758/s13428-011-0168-7

Mayo, L. H., Florentine, M., & Buus, S. (1997). Age of second-language acquisition and perception of speech in noise. *Journal of Speech, Language, and Hearing Research*, *40*(3). https://doi.org/10.1044/jslhr.4003.686

Meador, D., Flege, J. E., & Mackay, I. R. A. (2000). Factors affecting the recognition of words in a second language. *Bilingualism: Language and Cognition*. https://doi.org/10.1017/s1366728900000134

McQueen, J. M., & Huettig, F. (2012). Changing only the probability that spoken words will be distorted changes how they are recognized. Journal of the Acoustical Society of America, 131(1), 509-517. https://doi.org/10.1121/1.3664087.

Muntendam, A., van Rijswijk, R., Severijnen, G., & Dijkstra, T. (2022). The role of stress position in bilingual auditory word recognition: Cognate processing in Turkish and Dutch. *Bilingualism: Language and Cognition*, 25(4), 679-690.

Navarra-Barindelli, M. E. (2022). Reconocimiento de palabras en una segunda lengua: efectos interlingüísticos en las modalidades visual y auditiva, *doctoral thesis*, University of the Basque Country (UPV).

Obleser, J., Wise, R. J., Dresner, M. A., & Scott, S. K. (2007). Functional integration across brain regions improves speech perception under adverse listening conditions. *Journal of Neuroscience*, 27(9), 2283-2289.

Pae, H. K. (2020). Script Effects as the Hidden Drive of the Mind, Cognition, and Culture.

Radeau, M., Morais, J., & Segui, J. (1995). Phonological priming between monosyllabic spoken words. *Journal of Experimental Psychology: Human Perception and Performance*, 21(6), 1297.

Sanchez-Casas, R. M., Davis, C. W., & Garcia-Albea, J. E. (1992). Bilingual Lexical Processing: Exploring the Cognate/ Non-cognate Distinction. *European Journal of Cognitive Psychology*. https://doi.org/10.1080/09541449208406189

Savin, H. B. (1963). Word- frequency effect and errors in the perception of speech. *The Journal of the Acoustical Society of America*, 35(2), 200-206.

Scharenborg, O., & van Os, M. (2019). Why listening in background noise is harder in a non-native language than in a native language: A review. En *Speech Communication* (Vol. 108). https://doi.org/10.1016/j.specom.2019.03.001

Schulpen, B., Dijkstra, T., Schriefers, H. J., & Hasper, M. (2003). Recognition of Interlingual Homophones in Bilingual Auditory Word Recognition. *Journal of Experimental Psychology: Human Perception and Performance*, *29*(6). https://doi.org/10.1037/0096-1523.29.6.1155

Schwartz, A. I., Kroll, J. F., & Diaz, M. (2007). Reading words in Spanish and English: Mapping orthography to phonology in two languages. *Language and Cognitive Processes*, *22*(1). https://doi.org/10.1080/01690960500463920

Shi, L. F. (2010). Perception of acoustically degraded sentences in bilingual listeners who differ in age of english acquisition. *Journal of Speech, Language, and Hearing Research*, *53*(4). https://doi.org/10.1044/1092-4388(2010/09-0081)

Shook, Anthony, and Viorica Marian. (2013). "The Bilingual Language Interaction Network for Comprehension of Speech." *Bilingualism: Language and Cognition*, 16(2), 304–324. https://doi.org/10.1017/S1366728912000466.

Sorin, C., & Thouin-Daniel, C. (1983). Effects of auditory fatigue on speech intelligibility and lexical decision in noise. *Journal of the Acoustical Society of America*, *74*(2). https://doi.org/10.1121/1.389839

Spivey, Michael J, and Viorica Marian. (1999). "Cross Talk between Native and Second Languages: Partial Activation of an Irrelevant Lexicon." *Psychological Science*, 10, 3281–3284.

Tabri, D., Chacra, K. M. S. A., & Pring, T. (2015). Speech perception in noise by monolingual, bilingual and trilingual listeners. *International Journal of Language & Communication Disorders*, 1-12.

Taler, V., Aaron, G. P., Steinmetz, L. G., & Pisoni, D. B. (2010). Lexical neighborhood density effects on spoken word recognition and production in healthy aging. *Journals* *of Gerontology - Series B Psychological Sciences and Social Sciences*, *65 B*(5). https://doi.org/10.1093/geronb/gbq039

Thomas, M. S., & Van Heuven, W. J. (2005). Computational models of bilingual comprehension. Handbook of bilingualism: Psycholinguistic approaches, 202-225.

Van Engen, K. J., Dey, A., Runge, N., Spehar, B., Sommers, M. S., & Peelle, J. E. (2020). Effects of age, word frequency, and noise on the time course of spoken word recognition. Collabra: *Psychology*, 6(1).

Van Hell, Janet G, and Ton Dijkstra. (2002). “Foreign Language Knowledge Can Influence Native Language Performance in Exclusively Native Contexts.” *Psychonomic Bulletin & Review* 9, 4, 780–789.

Van Hell, J. G., & Tanner, D. (2012). Second language proficiency and cross- language lexical activation. Language Learning, 62, 148-171.

Van Heuven, Walter JB, Ton Dijkstra, and Jonathan Grainger. (1998). “Orthographic Neighborhood Effects in Bilingual Word Recognition.” *Journal of Memory and Language* 39(3) 458–483.

Van Heuven, Walter JB. (2005). “Bilingual Interactive Activation Models of Word Recognition in a Second Language.” *Second Language Writing Systems*, 260–288.

Voga, M., Grainger, J., & Heuven, V. (2007). Cognate status and cross-script. *Memory & Cognition*. https://doi.org/10.3758/BF03193467

Yujian, L., & Bo, L. (2007). A normalized Levenshtein distance metric. *IEEE Transactions on Pattern Analysis and Machine Intelligence*. https://doi.org/10.1109/TPAMI.2007.1078

Zhang, X., & Samuel, A. G. (2018). Is speech recognition automatic? Lexical competition, but not initial lexical access, requires cognitive resources. *Journal of Memory and*

Language, 100, 32-50.

Ziegler, J. C., Muneaux, M., & Grainger, J. (2003). "Neighborhood effects in auditory word recognition: Phonological competition and orthographic facilitation." *Journal of Memory and Language* 48(4), 779-793.

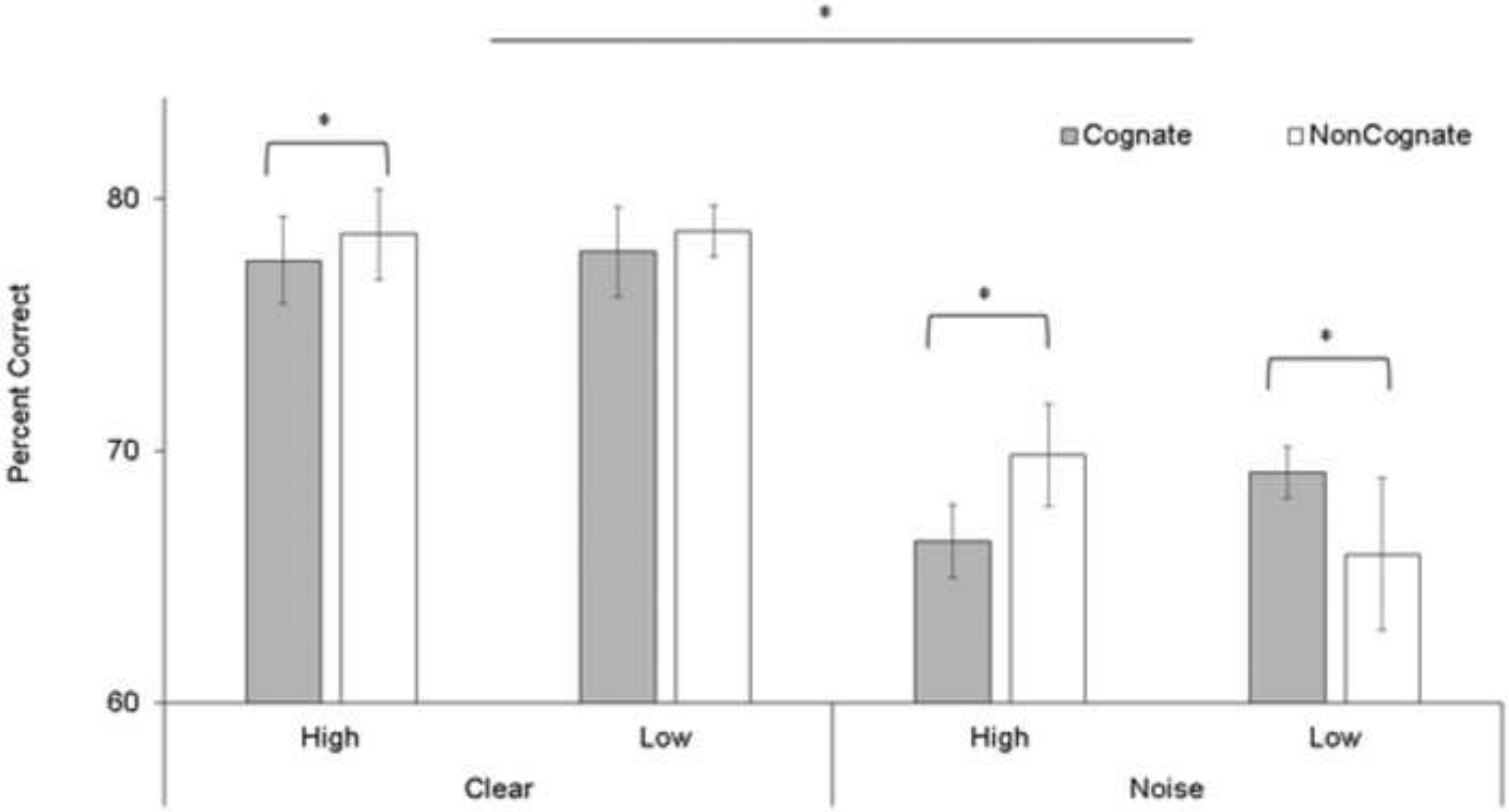
Zwitserlood, P., Dijkstra, A., and Lemhöfer, K. (2007) Separate contributions of form and meaning in bilingual word recognition: Evidence from auditory priming. MS. (pág. 266)

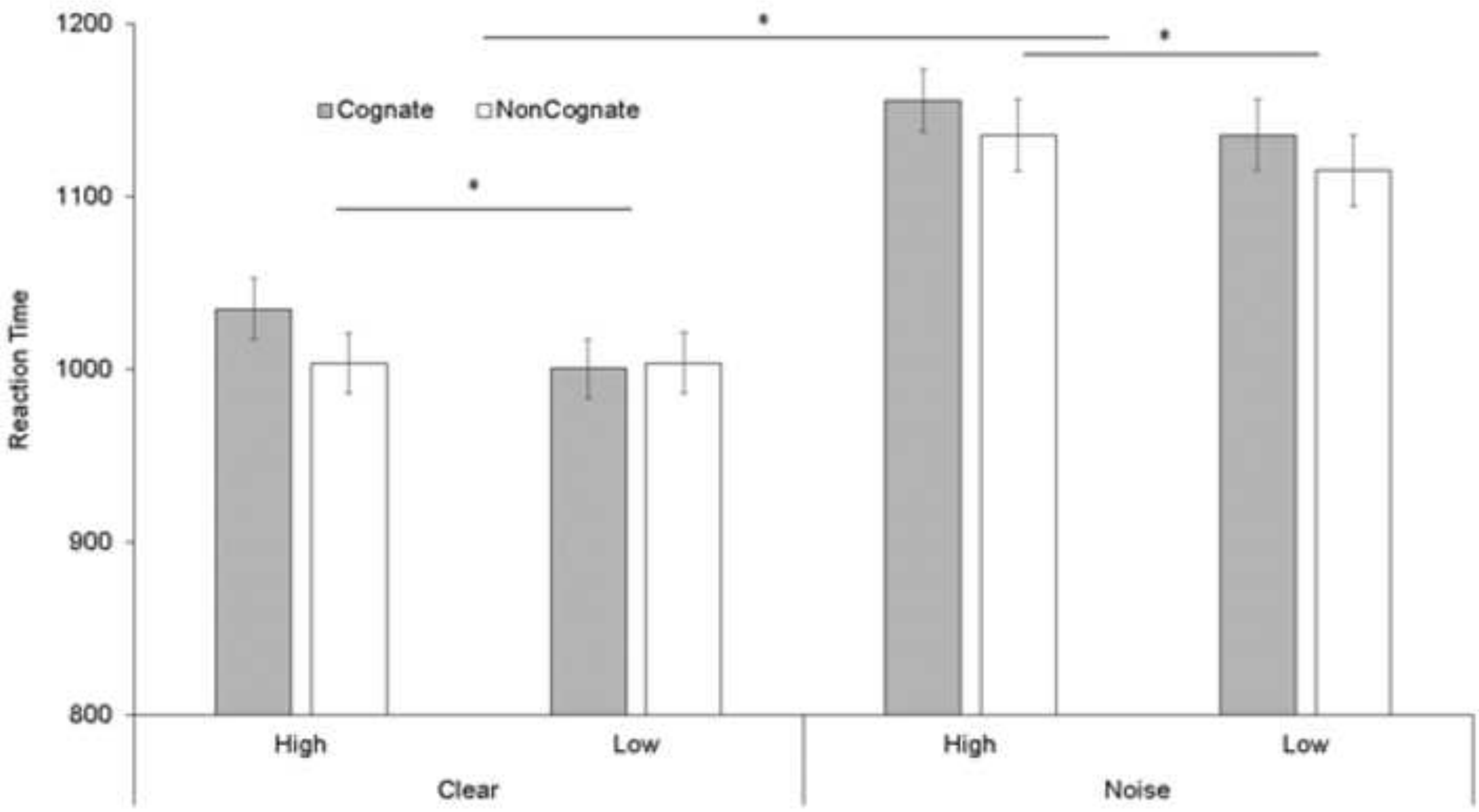
Figure Legends

Figure 1. Figure represents average percent accuracy across different conditions. Standard error bars represent standard errors of the mean. High = High PhonoNDtrans, Low = Low PhonoNDtrans

Figure 2. Figure represents mean reaction time across different conditions. Standard error bars represent standard errors of the mean. High = High PhonoNDtrans, Low = Low PhonoNDtrans

Figure 1


*
*
*
*
Cognate
NonCognate
80
70
60
Percent Correct
High
Low
High
Low
Clear
Noise



1200
1100
1000
900
800
Reaction Time
Cognate
NonCognate
*
*
*
High
Low
High
Low
Clear
Noise

Table 1. Participant Profile. Values in parentheses represent standard deviations. AoA stands for age of acquisition. BEST score is the mean score on the BEST test (described in manuscript).

Participants Profile	44 (33 female)
Age	25.57 (6.08)
Spanish AoA	0
English AoA	5.91 (2.34)
Spanish BEST score	65 (0.0)
English BEST score	57.95 (7.20)

Table 2. L1 PhonoND$_{trans}$ manipulation. Table shows Means with standard deviations in parentheses showing the number of L1 neighbors for the L1 translation of the L2 target.

	Cognates		Non-Cognates	
	Low PhonoND$_{trans}$	High PhonoND$_{trans}$	Low PhonoND$_{trans}$	High PhonoND$_{trans}$
L2 frequency	30.68 (59.33)	26.62 (42.17)	29.81 (48.75)	28.02 (39.82)
Nº letters	6.98 (1.17)	6.92 (1.19)	7.09 (1.44)	7.22 (1.50)
Nº syllables	2.32 (.55)	2.22 (0.53)	2.21 (0.58)	2.34 (0.58)
Nº phonemes	6.18 (1.17)	6.08 (1.18)	5.94 (1.41)	6 (1.54)
L2 phonological neighbors	1.31 (2.34)	1.36 (2.26)	1.38 (1.85)	1.74 (2.37)
L1 phonological neighbors	1.81 (1.04)	9.27 (10.08)	1.74 (0.98)	10.40 (7.44)
L2 orthographic neighbors	0.88 (1.58)	0.91 (1.05)	1.05 (1.59)	1.01 (1.19)
Phonological cognate rate	0.38 (0.13)	0.37 (0.10)	0.07 (0.07)	0.08 (0.07)

Table 3. L2Freq Design. Table shows Means with standard deviations in parentheses.

	Cognates		Non-Cognates	
	Low Frequency	High Frequency	Low Frequency	High Frequency
L2 frequency	6.54 (3.98)	58.02 (65)	7.57 (4.77)	51.70 (54.25)
Nº letters	6.84 (1.07)	7 (1.28)	7.04 (1.49)	6.82 (1.45)
Nº syllables	2.22 (.64)	2.20 (0.52)	2.22 (0.51)	2.16 (0.65)
Nº phonemes	6.04 (1.19)	6.08 (1.27)	5.82 (1.36)	5.76 (1.41)
L2 phonological neighbors	1.44 (2.96)	1.89 (2.93)	1.77 (3.44)	1.82 (2.33)
L1 phonological neighbors	6.25 (5.22)	6.99 (10.79)	7.96 (8.85)	7.66 (9.79)
L2 orthographic neighbors	0.96 (1.55)	1.15 (1.43)	1.08 (2.09)	1.20 (1.53)
Phonological cognate rate	0.39 (0.12)	0.37 (0.12)	0.07 (0.07)	0.08 (0.07)

Table 4. Lexical decision accuracy. Mean proportion of accurately recognized words. Standard deviations are reported in parentheses. Asterix denotes significance level of *p < .01, ** p < .005, *** p < .001. $\text{PhonoND}_{\text{trans}}$ = low phonological neighborhood density for target translation. SD= Standard deviation. Pbonf = Bonferroni corrected p-value.

Listening Condition	**$\text{PhonoND}_{\text{rans}}$**	**Cognate Status**	**Mean**	**SD**	
Clear	High	Cognates	0.80	0.11	**
		Non Cognates	0.85	0.11	
	Low	Cognates	0.83	0.12	
		Non Cognates	0.84	0.10	
Noise	High	Cognates	0.65	0.14	***
		Non Cognates	0.72	0.12	
	Low	Cognates	0.70	0.12	*
		Non Cognates	0.65	0.14	

< .01, ** < .005, *** < .001

Table 5. Mean reaction times (measured from onset target onset) in ms. Standard deviations are reported in parentheses. Asterix denotes significance level of *p < .01, ** p < .005, *** p < .001. Cog = Cognate, NonCog = Noncognate. $\text{PhonoND}_{\text{trans}}$ = low phonological neighborhood density for target translation. SD= Standard deviation.

Listening Condition	**$\text{PhonoND}_{\text{trans}}$**	**Cognate Status**	**Mean**	**SD**	
Clear	High	Cognates	1035	112	*
		Non Cognates	1003	111	
	Low $\text{PhonoND}_{\text{rans}}$	Cognates	1001	107	
		Non Cognates	1004	111	
Noise	High	Cognates	1155	115	
		Non Cognates	1135	131	
	Low	Cognates	1115	130	
		Non Cognates	1136	130	

Table 6. Lexical decision accuracy. Mean proportion of accurately recognized words. Standard deviations are reported in parentheses. Asterix denotes significance level of *$p < .01$, ** $p < .005$, *** $p < .001$.

Signal	**Frequency**	**Cognate Status**	**Mean**	**SD**	
Clear	High	Cognates	0.91	0.09	
		Non Cognates	0.89	0.09	
	Low	Cognates	0.72	0.15	***
		Non Cognates	0.79	0.13	
Noise	High	Cognates	0.76	0.13	
		Non Cognates	0.73	0.13	
	Low	Cognates	0.60	0.15	
		Non Cognates	0.61	0.13	

Table 7. Mean reaction times (measured from onset target onset) in ms. Standard deviations are reported in parentheses. Asterix denotes significance level of *p < .01, ** p < .005, *** p < .001. SD= Standard deviation.

Signal	**Frequency**	**Cognate Status**	**Mean**	**SD**	
Clear	High	Cognates	968	104	
		Non Cognates	987	101	
	Low	Cognates	1067	126	*
		Non Cognates	1038	118	
Noise	High	Cognates	1112	117	
		Non Cognates	1113	121	
	Low	Cognates	1172	126	
		Non Cognates	1171	132	

Appendix A, B, C