LEXICAL CATEGORY DIFFERENCES IN BILINGUAL PICTURE NAMING: IMPLICATIONS FOR MODELS OF LEXICAL REPRESENTATION

Yasmeen Faroqi-Shah[a*]
[a]University of Maryland

Yanni Kevas[a]
[a]University of Maryland

Ran Li[b]
[b]Boston University

In press. Bilingualism, Language, & Cognition

Acknowledgements:
We thank Kyra Paticoff for assistance with developing the stimuli, Jiae Yoon for assistance with data collection and analysis, and Molly Harman, Melissa Stockbridge, and Ayesha Hayat for response scoring.

Address for correspondence:
Department of Hearing and Speech Sciences
University of Maryland,
7251 Preinkert Drive, College Park, Maryland 20904 USA
yfshah@umd.edu

Keywords:
bilingual, noun, picture naming, translation, verb

ABSTRACT

Bilingual speakers are less accurate and slower than monolinguals in word production. This *bilingual cost* has been demonstrated primarily for nouns. This study compared verb and noun retrieval to better understand bilingual lexical representation and test alternate hypotheses about bilingual cost. Picture naming speeds from highly proficient English-Spanish bilinguals showed a smaller bilingual cost for verbs compared to nouns. Picture naming speeds were influenced by name agreement, age-of-acquisition and word length. Additionally, noun (but not verb) naming speed was predicted by word frequency. Experiment 2 examined two potential explanations for the smaller bilingual cost for verbs: verbs experience weaker cross-language interference (measured by translation speed) and smaller frequency effects. Both these predictions were confirmed, showing crucial differences between verbs and nouns and suggesting that cross-language facilitation rather than interference influences bilingual lexical retrieval, and that the frequency lag account of bilingual cost is more applicable to nouns than to verbs. We propose a Bilingual Integrated Grammatical Category model for highly proficient bilinguals to represent lexical category differences.

Bilingual speakers are constantly juggling two or more languages in their brain (we follow the conventional use of the word *bilingual* to refer to persons to who use two or more languages). One intriguing question is how words are mentally represented and accessed by bilingual speakers compared to monolinguals. Bilinguals may have a larger vocabulary, which not only includes translations of the same concepts but also several words and concepts unique to one language. Further, concepts may merge across languages in a way that diverges from conceptual representations of monolingual speakers (Ameel, Malt, Storms & Van Assche, 2009; Dong, Gui & MacWhinney, 2005). There is some (albeit limited) evidence that bilinguals produce fewer direct translation equivalents for verbs compared to nouns (Gentner, 1981; Prior, MacWhinney & Kroll, 2007; van Hell & de Groot, 1998). For instance, in a double translation task most of the original nouns, but not verbs, were preserved in the final translation (Gentner, 1981). And, in a single word translation task, bilinguals produced a wider range of translations for verbs compared to nouns (Prior et al., 2007). These differences between verbs and nouns highlight the need to further understand if and how the lexical category of a word influences bilingual lexical organization.

Differences between verbs and nouns

Verbs and nouns are processed in distinct neural regions (Faroqi-Shah, vander Woude & Sebastian, 2018). Morphosyntactic differences between verbs and nouns include distinct sentential roles, morphological markings, and the extent of subcategorization information. Semantically, nouns refer to entities that can be counted or individuated, while verbs refer to events and actions that are temporally transient; nouns are more weighted with sensory-perceptual attributes, while verbs predominantly have functional-motoric associations (O'Grady, 1997; Warrington & Shallice, 1984). Given these differences, and the noun-centric focus of most empirical and theoretical research on bilingual lexical representation, this study aims to advance current understanding of bilingualism by comparing the characteristics and psycholinguistic predictors of verb and noun retrieval.

In monolinguals, numerous studies indicate that verbs are more challenging to retrieve and produce than nouns. Cross-linguistically, children acquire verbs later than nouns (Gentner, 1982; Haman et al., 2017). Verb retrieval is more vulnerable to neuropathology than noun retrieval (Matzig, Druks, Masterson & Vigliocco, 2009). In adults, picture naming response times are longer for action pictures than object pictures across languages, as revealed by Szekely et al. (2005) for a large set of action and object pictures of the International Picture Naming Project (IPNP) (Bates et al., 2003). These response time differences persisted even after controlling for variables such as lexical frequency, age-of-acquisition, and picture name agreement (Szekely et al., 2005). In the present study, we refer to the slower action naming speed as a *verb cost*. There are also qualitative differences between these two lexical categories. For example, compared to object naming, action naming is more influenced by name agreement (Kauschke & Frankenberg, 2008) and cognitive control (Shao, Roelofs & Meyer, 2012), and is less influenced by lexical frequency (Szekely et al., 2005) and imageability ratings (Kauschke & Frankenberg, 2008). In light of these quantitative (verb cost) and qualitative (psycholinguistic predictors) differences in monolinguals, it is unclear if there are additional representational and retrieval differences between verbs and nouns in bilinguals.

The Bilingual Cost

Bilingual speakers retrieve words more slowly and experience more tip-of-the-tongue states than monolingual speakers, which we refer to as *bilingual cost* (Gollan & Acenas, 2004; Gollan, Montoya, Fennema-Notestine & Morris, 2005; Ivanova & Costa, 2008; Kohnert, Hernandez & Bates, 1998). When bilinguals perceive or retrieve words in one language, it automatically activates related words within- and across- languages (Dijkstra & Van Heuven, 2002; Grainger, 1993; Marian & Spivey, 2003). This cross-language activation could strengthen the lexical representations of the cross-language translations. Conversely, the activated translations could cause cross-language interference or competition during lexical selection (Green, 1998; Kroll, Bobb, Misra & Duo, 2008; Sandoval, Gollan, Ferreira, & Salmon, 2010; Sullivan, Poarch & Bialystok, 2018). Given some evidence that verb translations are more variable across languages (Gentner, 1981; Prior et al., 2007), cross-language activation and interference allow us to make two contrasting predictions about how the bilingual cost may be manifested across lexical categories. On the one hand, fewer direct connections between verb translations implies that lexical representations of verbs are less likely to get consolidated by automatic cross-language spreading of activation (Wolff & Ventura, 2009). This predicts that bilinguals would show an even larger bilingual cost for verb naming compared to noun naming. The converse argument is that verbs will show a smaller bilingual cost because fewer cross-language lexical competitors are activated during verb retrieval and hence there is less cross-language interference for verbs compared to nouns. Only two picture naming studies provide insights into verb-noun differences. In terms of accuracy, six-year old Russian-German bilingual children had no bilingual cost for verbs while they had a bilingual cost for noun naming (Klassert, Gagarina and Kauschke, 2014). Picture naming speed in Mandarin-English bilingual adults revealed a smaller verb cost compared to a noun cost (Li, Faroqi-Shah & Wang, 2019). Both these studies suggest smaller bilingual costs for verbs; indicating the need for further research on bilingual cost in the context of lexical categories.

Studies of the bilingual cost (using nouns) have identified some influencing factors. These include, the age-of-acquisition of individual concepts (Palmer & Havelka, 2010), age of L2 acquisition (Bylund, Abrahamsson, Hyltenstam & Norrman, 2019), phonological similarity of translations (Sadat, Martin, Magnuson, Alario & Costa, 2016), and word frequency (Gollan et al., 2008). Of these, word frequency has received considerable attention, with bilinguals showing a larger frequency effect (slower naming of less frequent words), especially in their less dominant language (Duyck, Vanderelst, Desmet, & Hartsuiker, 2008; Gollan et al., 2008; but see Sadat et al., 2016). Given that verbs are less influenced by frequency in monolinguals (Bonin, Boyer, Méot, Fayol, & Droit, 2004; Cuetos & Alija, 2003; Shao et al., 2012; Szekely et al., 2005), it is crucial to examine frequency effects across lexical categories in bilinguals to understand bilingual (verb vs. noun) costs. Frequency also interacts with bilinguals' ability to translate between languages (De Groot, 1992; Li et al., 2019), showing the importance of examining frequency effects along with translation. Translation ability (both accuracy and speed) is often used as a proxy measure of cross-language connections (Kroll & Stewart, 1994; Kroll, van Hell, Tokowicz, Green, 2010). Given that the interpretation of verb-noun differences in bilingual cost hinges on the strength of cross-language connections, we examine cross-language connections by measuring translation speeds across lexical categories.

In addition to uncovering bilingual lexical organization, a comparison of verb and noun naming in bilingual speakers could help us adjudicate between different theoretical accounts of the bilingual cost. The dominant theory of bilingual cost is based on the premise that compared to monolingual speakers, bilinguals typically have less language experience in any one language. As a result, lexical and phonological representations of bilinguals have less practice overall and may be less ingrained, less precise, with weaker mappings between semantics and phonology, leading to less automatic word retrieval. This *frequency lag hypothesis* (also called *weaker links hypothesis*) proposes that the bilingual-monolingual difference in lexical retrieval is a quantitative difference, and the underlying mechanism is a frequency effect (Gollan et al., 2008). That is, just as in monolinguals, less frequently used words are less accessible than words that are used more frequently. Hence, frequency effects are proposed to be larger for bilinguals, especially in the non-dominant language. Several studies have confirmed a larger frequency effect for bilinguals (e.g., Duyck, Vanderlest, Desmet & Hartsuiker, 2008; Gollan et al., 2008, 2011; Ivanova & Costa, 2008, Lemhöfer et al., 2008; Li et al., 2019; Sullivan et al., 2018). However, a bilingual frequency lag has not been reported in the dominant language (Duyck et al., 2008; Li et al., 2019), when bilinguals and monolinguals are matched for language proficiency (Diependaele et al., 2013; Gollan et al., 2011), when overall response speed is considered (Sadat et al., 2016), or when phonological similarity is factored in (Sadat et al., 2016).

The bilingual cost has also been explained on the assumption that word retrieval in bilinguals encounters greater lexical competition than it does for monolinguals because related words from both languages are co-activated (Green, 1998; Hall, 2011; Kroll, Bobb, Misra, & Guo, 2008; Kroll & Stewart, 1994; Lee & Williams, 2001; Sandoval et al., 2010; Van Hell & de Groot, 1998). This cross-language competition occurs over and above the within-language lexical competition that all speakers (monolingual and bilingual) encounter, and could cost them word selection time and accuracy. Empirical support for this *cross-language interference hypothesis* (also referred to as *competition hypothesis*) comes from cross-language intrusions (Sandoval et al., 2010), slower naming in one language if the same words have just been named in the other language (Misra, Guo, Bobb & Kroll, 2012), and the interference of picture naming in the presence of cross-language semantic or phonological distractors (Hermans et al., 1998). However, there is evidence against cross-language interference. For instance, picture naming is facilitated when translations are presented as distractors in a picture word interference paradigm (Costa, Miozzo, & Caramazza, 1999; Dylman & Barry, 2018), or when pictures are more easily translatable between languages (Gollan et al., 2005; Li et al., 2019). Further, pictures of nouns whose translations are phonologically similar (cognates) are named faster (Costa, Caramazza & Sebastian-Galles, 2000). In all these instances, translations are found to facilitate rather than interfere with noun retrieval, and we revisit this translation facilitation in the General Discussion.

In sum, two accounts of bilingual cost stem from research on noun retrieval: lower language use (frequency lag/weaker links) and cross-language interference. While there is evidence in favor of both accounts, not all empirical findings can be explained by any one account. One way to adjudicate between these accounts and gain a better understanding of bilingual word retrieval is to examine frequency and translatability effects in verbs. While the original accounts do not explicitly refer to lexical category differences, the accounts can be tested against each other by how well they accommodate findings across lexical categories.

The present study

The overarching goal of this study was to examine verb retrieval in bilinguals to elucidate bilingual lexical representation and test alternate hypotheses about bilingual cost. We studied verb and noun retrieval in fluent college-aged English-Spanish bilinguals. In Experiment 1, we first asked if bilinguals differ from monolinguals in their verb and noun retrieval. We examined this in terms of both qualitative and quantitative differences. The qualitative analysis examined factors the influence of psycholinguistic variables (Szekely et al., 2005). The quantitative analysis examined the magnitude of bilingual cost across verbs and nouns.

In Experiment 2, we tested the two theoretical accounts for the bilingual cost (frequency lag and cross-language interference) by examining the effect of lexical frequency and word translatability across noun and verb naming. The frequency lag/weaker links account predicts the bilingual cost to be similar for verbs and nouns as long as these stimuli are matched for frequency. The cross-language interference account predicts a negative effect of translatability, that is, words that can be more easily translated across languages will be named more slowly due to greater interference from the translations.

Experiment 1

This experiment examined bilingual picture naming speeds for the entire set of object and action pictures from the International Picture Naming Project (IPNP, Bates et al., 2003; Szekely et al., 2005). We first examined the influence of psycholinguistic predictor variables (qualitative differences) across lexical categories. The choice of predictors was based on what has been typically examined in picture naming studies (Bonin et al., 2004; Cuetos et al., 2006; Szekely et al., 2005), and included conceptual-semantic factors (age of acquisition, conceptual complexity, visual complexity, complex words, shared name across pictures) and lexical-phonological factors (frequency, word length, initial frication). We added lexical category and bilingual status as predictors. Next, we examined the magnitude of bilingual verb versus noun cost (quantitative difference).

Methods

Participants

Twenty college students participated (15 females, 5 males; Mean age = 20.2 years). Participant details are in Table 1. All participants considered themselves to be highly proficient in English and Spanish, and had acquired both languages before 11 years of age. Based on the Bilingual Language Profile (BLP, Birdsong, Gertken, & Amengual, 2012), there was no difference between the ages of acquisition of English and Spanish ($t(19)=1.3$, $p>.05$). The BLP yields a *language dominance index* by subtracting total scores of individual language ratings. The language dominance index (Mean = 61, SD = 26.5) is in the middle quartile, indicating high proficiency of both languages (allowable range is -218 to 218). English proficiency scores were higher ($t(19) = 2.9$, $p < 0.01$) showing English dominance. Henceforth, we refer to English as L1 (dominant language) and Spanish as L2 (less dominant language).

--------------Table 1----------

Materials

Picture stimuli were black-and-white line drawings of 520 objects and 275 actions from the IPNP (Bates et al., 2003). For each picture, the IPNP database provides empirically determined dominant names, naming speeds. It also provides name agreement, target name's word length in characters, whether it is a compound word (e.g., firetruck), word frequency (Baayen, Piepenbrock, & van Rijn, 1993), objective age of acquisition (Fenson et al., 1994), conceptual complexity (number of items in the picture), visual complexity (jpeg file size), and items with a shared name (words with noun-verb homophones). Overall, as reported in Table 3 of Szekely et al. (2005), action pictures had significantly shorter word length, higher word frequency, later age of acquisition, greater visual and conceptual complexity, higher homophony and fewer instances of compound words. The only parameter in which action and object names did not differ was frication in the word initial position.

Procedure

After providing informed consent, participants filled out a background questionnaire and the Bilingual Language Profile (Birdsong et al., 2012). Participants were tested individually in each language on separate days at least one week apart. The sequence of testing language (Spanish or English) and word category (noun or verb) was counterbalanced across participants. We followed the procedures described in norming studies of IPNP (Szekely et al., 2005). Participants were instructed to name pictures using a single word as quickly and accurately as possible and to avoid coughs, false starts, and hesitations. Each trial began with a centered fixation cross "+" for 200ms, followed by the target picture for 3000ms. The next trial began 1000ms after the voice key detected a response or after 3000ms. There was a short break after every 50 trials. For each block (verb, noun, English, Spanish), participants were given two practice trials with pictures that were not experimental stimuli. DMDX (Forster & Forster, 2003) was used for stimulus presentation and measurement of voice onset latencies. During the testing, a research assistant took notes regarding accuracy and possible RT contaminations (coughs, lip smacking etc.). Responses were audio-recorded for later verification and manually checking response times.

Data analysis

Following the procedures used by Szekely et al. (2005), valid responses were those with the target name and usable response times (voice key was trigged and there were no coughs, hesitations, false starts, or prenominal verbalization such as "that's a ball"). Based on the range of reaction times reported by Szekely et al. (2005), valid responses that were faster than 600ms and slower than 3000ms were excluded as outliers. Statistical analyses were performed on the remaining responses. For statistical analyses monolingual picture naming times were obtained from the IPNP database, which provides mean picture naming times collapsed across participants

(Szekely et al., 2005). The IPNP participants were native speakers of English with no other language exposure prior to 12 years of age (p. 9). We restricted our monolingual comparisons to English speakers and did not use Spanish speakers' data because action naming times for Spanish were unavailable from the IPNP database and it was not clear if the native Spanish speakers (college students in Tijuana, Mexico) were monolingual (Bates et al., 2003). One of the actions (act58) was excluded from analysis because its target name was a noun (*tornado*). All statistical analyses were conducted using SPSS (IBM corporation, version 24.0).

Results

Descriptive details of the bilingual naming responses and the comparable monolingual naming responses reported by Szekely et al. (2005) are in Table 2.

--------------Table 2----------

Predictors of naming latencies

To examine factors that predict naming speeds of verbs and nouns in bilinguals, stepwise regressions were conducted to test the contribution of each factor when other factors are controlled (as per Szekely et al., 2005). Three sets of regressions were conducted. First, separate regressions were conducted for object and action naming to examine the contribution of the factors used by Szekely et al. (2005): word length, initial frication, word frequency (Baayen et al., 1993), age of acquisition (Fenson et al., 1994), objective visual complexity, conceptual complexity, items with a shared name, and compound words (e.g., firetruck). Second, we combined the object and action naming data into a single regression model and assessed the contribution of lexical category and name agreement. Finally, we combined bilingual and monolingual data across object and action naming to assess the additional contribution of bilingualism. The results of the three regression analyses are in Table 3, which shows the standard regression coefficients and the unique variance contributed by each predictor after all other predictors had been entered into the regression.

--------------Table 3----------

In the first set of regression analyses, the model was significant for both object (R^2 = 11.6%, $p < .001$) and action (R^2 = 6.9%, $p < .05$) naming. For object naming, earlier age of acquisition, higher lexical frequency, shorter word length and shared name significantly predicted faster naming times (Table 3a). For actions, naming speed was predicted by early age of acquisition, the presence of a shared name and lower conceptual complexity. Comparing the regression patterns between bilingual and monolingual speakers (from Szekely et al., 2005, Table 10) shows that, while this eight-predictor model accounts for a smaller variance in bilingual naming speed, the overall pattern of significant predictors is largely similar across the two groups, with minor differences. For noun naming, bilinguals showed a word length effect and an absence of a conceptual complexity effect. For verb naming, bilinguals did not show word length and frequency effects (unlike the monolingual group).

Including lexical category and name agreement in the second set of regression analyses increased the predictive accuracy of the model to 28.4% ($p < .001$) (Table 3b) compared to 56.7% for monolinguals (Table 13 of Szekely et al., 2005). For both groups, the significant predictors in decreasing order of importance were: higher name agreement, lexical category (noun), earlier age of acquisition and shorter word length. Additionally, monolingual naming times were faster for simple (not compound) words and lower conceptual complexity. Replacing the name agreement values with those calculated from the current bilingual group slightly increased the variance explained by name agreement from -0.41 to -0.44.

Finally, inclusion of bilingual status as a dichotomous variable in a third regression model increased the model variance to 48% ($p < .001$), and the significant predictors in decreasing importance were higher name agreement, absence of bilingualism, noun, earlier age of acquisition, shorter word length, lower conceptual complexity and absence of frication (Table 3c). As a further check on model fit, we re-ran the regression by 1) replacing the CELEX frequencies with SUBTLEX frequencies (Brysbaert & New, 2009), and 2) excluding all cognates. Cognates were defined as items whose Spanish and English target names were related in form (phonological and/or orthographic, e.g., *serve-servir*), or whose synonym was related in form (*cocodrillo – alligator*). 46% (N=240) and 37.4% (N=103) of object and action stimuli respectively were cognates. The model fit changed slightly (50.7% with SUBTLEX, 47% with non-cognates, $p < .001$).

Bilingual cost: verbs and nouns

The naming latencies are illustrated in Figure 1. To examine the quantitative effect of bilingualism on word naming, English noun and verb naming times were compared between bilingual and monolingual speakers using a linear mixed effects model (LME) on raw (untransformed) response times (Lo & Andrews, 2015) with language group (monolingual, bilingual), lexical category (noun, verb) and the interaction term as fixed factors and items as the random factor. The intercept was included in the model for fixed and random factors and random slopes were also included[1]. There was a main effect of language group ($\beta = -86.7$, SE = 13.9, t = -6.2, $p < .001$) and word type ($\beta = -219.8$, SE = 19.6, t = -11.2, $p < .001$). In addition, there was a significant interaction between language group and word type ($\beta = -40.4$, SE = 17.2, t = -2.3, $p < .05$). That is, bilinguals were slower than monolinguals for both objects and actions, showing a

[1] Trial number could not be included in the model because monolingual RTs did not have trial information (Szekely et al., 2005)

bilingual cost (mean difference in RT = 106.5 ms, SE = 13.8), actions were named slower than objects, showing a *verb cost* (mean difference in RT = 239.7 ms, SE = 13.8), and the bilingual cost was smaller for actions than for objects (mean difference in RT = 127.1 ms versus 86 ms).

--------------Figure 1----------

The results were unchanged when cognates were excluded. There was a main effect of group (β = -.026, SE = .005, t = -4.6, p <.001) and word type (β = -.07, SE = .007, t = -8.8, p < .001), and an interaction (β = -.03, SE = .006, t = -4.06, p < .001). Therefore, the smaller bilingual cost for actions was not because there were more verb cognates.

Comparison of Spanish and English

We compared bilingual speakers' naming speed across their two languages (L1 and L2) and word categories using LME with language (English, Spanish), lexical category (noun, verb) and their interaction term as fixed factors, items and trial as the random factors and including random slopes and random intercepts for both fixed and random factors. Picture naming latencies were significantly slower in Spanish compared to English, showing a L2 cost (β = -177.6, SE = 17.7, t = 10.03, p < .001), and for actions compared to objects, showing a verb cost (β = -122.1, SE = 16.5, t = -7.3, p < .001). There was a significant interaction between language and word category (β = 62.4, SE = 21.1, t = -2.9, p < .01), showing that the verb cost was smaller in Spanish (122.4 ms) compared to English (219.2 ms). Or stated differently, Spanish naming latencies were much slower than English naming latencies for nouns (211.7 ms) than for verbs (115.3 ms).

Discussion

Experiment 1 asked if bilinguals show qualitative and quantitative differences from monolinguals in their action and object naming performance. Monolingual performance was extracted from naming times published by Szekely et al. (2005) for the same stimuli.

Predictors of bilingual word retrieval speed

One predictor showed a robust effect on naming times across all regression analyses: age of acquisition (AoA). AoA has been identified in numerous prior studies (e.g. Ellis & Morrison, 1998; Lachman, Shaffer, & Hennrikus, 1974; Palmer & Havelka, 2010), and the current findings highlight the importance of this factor for bilingual naming times. AoA effects are assumed to arise due to conceptual complexity because easier concepts (such as concrete entities) are acquired earlier. AoA effects are also considered to represent connection strengths between semantic and lexical representations as these are strengthened over time with repeated retrieval (Ellis & Lambon Ralph, 2000). Studies have also shown that when AoA is considered, lexical frequency effects are diminished (e.g. Morrison, Hirsh & Duggan, 2003). This might explain the relatively modest influence of frequency on naming times in the present study (Table 3a). Moreover, frequency effects disappeared when name agreement and lexical category were introduced into the regression for both monolinguals and bilinguals (Table 3b and c). This is an important finding, as it shows the limits of frequency effects on word retrieval. It also shows that an account of bilingual cost that solely relies on usage frequency might be too narrow in scope. Name agreement reflects the different lexical labels that might be competing for selection. Items with low name agreement take longer to name because of the need to resolve among these alternate lexical labels. The robust effect of lexical category on naming times indicates that, for both monolinguals and bilinguals, the slower naming times of verbs cannot be explained away by other factors such as age of acquisition, name agreement or conceptual complexity (Szekely et al., 2005). Finally, two articulatory-phonological variables showed an effect on naming times: word length and initial frication. Word length effects are consistent with the view that articulation is initiated after all syllables are planned (Roelofs, 1996) and hence longer words have slower naming times. Initial frication shows an effect on naming times because word onset is harder to detect by voice key trigger or manual coding because words with initial fricatives have a more gradual onset, compared to words that begin with articulatory closure such as stops and affricates. In summary, the regression analyses highlight two main points. First, naming times in bilinguals and monolinguals are influenced by qualitatively similar predictors, with robust effects of AoA, name agreement and lexical category. Second, bilingualism (bilingual cost) and lexical category (verb cost) have a significant influence on naming speed, while frequency has weak effects on naming speed.

Bilingual cost: verbs and nouns

This study found a bilingual cost, which was larger for Spanish (L2) compared to English (L1), replicating prior studies (Bylund et al., 2019; Gollan & Acenas, 2004; Gollan et al., 2005; Ivanova & Costa, 2008; Kohnert et al., 1998). The crucial question was whether bilingual cost differed across lexical categories. In both languages, the bilingual verb cost was smaller in magnitude than the bilingual noun cost. And, in the bilingual group, L2-L1 difference for verbs was smaller than the L2-L1 difference for nouns. Our study replicates Li et al.'s (2019) findings with Mandarin-English speakers by using a much larger set of IPNP stimuli.

Now let's examine the two theories of bilingual cost. The frequency lag/weaker links theory gave two predictions: a larger bilingual cost for the less dominant language and no difference in bilingual cost across lexical categories. While the first prediction was supported, the second prediction of was not. Rather than entirely dismissing the frequency lag account, we need to consider the possibility that verb retrieval inherently differs from noun retrieval and is less affected by frequency, as we found in the regression analyses and has been reported in prior studies of monolinguals (Bonin et al., 2004; Cuetos & Alija, 2003; Shao et al., 2012; Szekely et al., 2005). In experiment 2, we aim to replicate the smaller influence of frequency on verbs (compared to nouns) by directly manipulating the lexical frequency of target names.

For the cross-language interference account, verbs were predicted to show a smaller bilingual cost based on the assumption that verb translations are less tightly linked across languages (Prior et al., 2007; van Hell & De Groot, 1998). While this prediction was supported, one needs to test the underlying assumption that cross-language connections for verbs are weaker than for nouns. In Experiment 2, this was done by eliciting translations for nouns and verbs, and then examining the relationship between translation speed and picture naming speed.

Experiment 2

The main goal of this experiment was to better understand the smaller bilingual verb cost found in Experiment 1. The crucial comparisons were between lexical categories and between L1 and L2, and not across monolingual and bilingual groups. To confirm that the frequency lag/weaker links alone is insufficient to explain verb retrieval costs in bilinguals (Gollan et al., 2008), this experiment compared the magnitude of frequency effect across lexical categories. To examine if a smaller cross-language interference was the source of a smaller verb cost, the connection strength across translation equivalents was tested by comparing translation speed for each lexical category. Translation speed has been used as a proxy for the strength of cross-language connections in prior studies (de Groot, 1992; Kroll & Stewart, 1994). For the cross-language interference account to successfully explain the smaller bilingual verb cost, we should observe longer translation times (~weaker cross-language connections) for verbs compared to nouns. Additionally, we expect to observe the general patterns predicted by each account: slower naming times and a larger frequency effect in the non-dominant language as predicted by the frequency lag/weaker links account, and a negative association between naming speed and translation speed is predicted by the cross-language interference/competition account. Given that both frequency and cross-language interference could play a role in bilingual language production (in addition to other factors not tested in this study, such as cognate status), these two variables were analyzed in a single statistical model.

Methods

Participants

A new group of twenty highly proficient English-Spanish bilinguals were recruited (18 females, 2 males; Mean age = 21 years). All participants were exposed to Spanish at birth, and all (but one) were exposed to English before the age of 12 years. Participant details are in Table 1. Self-ratings of language proficiency using the Bilingual Language Profile (Birdsong et al., 2012) showed a mean language dominance score of 32.3 (SD = 38.3). English proficiency was higher than Spanish proficiency ($t(19) = 4.2$, $p < 0.001$), showing English dominance (L1 = English, L2 = Spanish). Additionally, proficiency was objectively determined by an oral interview in both languages ("What do you do on a typical Monday?") and an online lexical test (*Lexical Test for Advanced Learners of English,* LexTale, www.lextale.com, Lemhöfer & Broersma, 2012). The oral interviews were scored according to the American Council on the Teaching of Foreign Languages' (ACTFL) proficiency guidelines (Swender et al., 2012), and participants with ratings of Advanced, Superior, or Distinguished in both languages were included. The mean online LexTale score was 84.2% (SD = 10.4).

Stimuli

One hundred object pictures (50 Low Frequency (LF), 50 High Frequency (HF)) and 94 action pictures (50LF, 44HF) were selected from the IPNP stimuli (Supplementary file). Words were categorized as low or high frequency based on both English ($SUBTLEX_{us}$, Brysbaert & New, 2009) and Spanish (SUBTLEX-ESP, Cuetos, Glez-Nosti, Barbon & Brysbaert, 2011) spoken word frequencies. The LF words varied in frequency from 0 – 25/million and the HF words had a frequency greater than 40/million. Verb and noun stimuli can differ across numerous dimensions (imageability, homophony etc.) that is nearly impossible to match them on all variables (as noted by Szekely et al., 2005), and doing so could result in a very skewed set of stimuli that are not characteristic of prototypical nouns and verbs. Hence, we matched verbs and nouns on just the crucial variable of interest, word frequency. The verbs and nouns did not differ in log frequency values (English: $t(192) = 1.4$, $p > .05$); Spanish: $t(192) = 1.8$, $p > .05$). Given the high influence of name agreement on naming times in Experiment 1, we matched the HF and LF stimuli on English name agreement using the H-statistic (Bates et al., 2003) (nouns: $t(98) = -1.25$, $p > .05$; verbs: $t(98) = 1.50$, $p > .05$). Seventeen nouns and 11 verbs were either direct cognates or cognates of close synonyms (e.g. *robar-steal*). Given that Spanish and English share a large number of cognates, we included the cognates to get a more ecologically realistic distribution of stimuli.

Procedures

Participants were tested individually over two sessions at least a week apart. The first session measured language proficiency and picture naming in one language. The second session included picture naming in the other language and the translation task. The sequence of language (Spanish or English) and word category (verb or noun) was counterbalanced across participants. Stimuli were presented in a random sequence for both picture naming and translation.

Picture-naming task: The procedures were identical to Experiment 1.

Translation task: Printed words (Spanish picture names) were presented individually in two blocks (verbs and nouns). Participants were asked to translate the words from Spanish to English as quickly as possible. The trial and stimulus durations were the same as the picture-naming task.

Data Analysis

Procedures for recording and checking response times, determining valid responses and outlier exclusion were the same as Experiment 1 (and Li et al., 2019; Szekely et al., 2005). The distribution of responses is given in Table 2. Statistical analyses were performed using SPSS, IBM Corporation, version 24.0. Unless otherwise stated, linear mixed effect models were tested with participants and items as random effects with random slopes and intercepts included for fixed effects. We first examined translation speed differences across lexical categories to test the prediction that verbs generally have poorer translatability (and hence longer translation speeds). Next, we examined the effects of lexical category, frequency and translatability on picture naming speed in each language. To examine the effect of translatability on picture naming speed, each individual participant's naming responses were sorted into high and low translatability items based on translation speed obtained from the translation task for that participant. If a translation was invalid (3000 < ms < 500), the corresponding picture name was excluded. If a translation was incorrect, the corresponding picture name was grouped into the low translatability category. Thus, the translatability for each item for each participant was individually determined and converted into a dichotomous variable.

Results

Picture naming and translation responses are illustrated in Figure 2 and the results are shown in Tables 2 and 4. In the picture naming task, verbs were slower than nouns (mean difference = 232.3ms, SE = 13), Spanish naming was slower than English naming (mean difference = 94.9ms, SE = 10.8), and the Spanish-English difference was smaller for verbs (mean difference = 52ms, SE = 8) than for nouns (mean difference = 137.9ms, SE = 10.1). That is, similar to Experiment 1, the L2 cost (slower naming in L2) was smaller for verbs than for nouns. In the translation task, participants did not differ in accuracy between nouns and verbs (Wilcoxon signed-ranks, $Z = .45$, $p > .05$). This comparable translation accuracy for verbs and nouns is important in interpreting translation speed differences because it eliminates the possibility of a "speed-accuracy trade-off". That is, if verbs had lower translation accuracy, then it could be argued that only "easy" verbs were accurately translated, resulting in faster verb translation speeds. In the translation task, verbs (M = 1136ms, SE = 32.9) were translated faster than nouns (M = 1459ms, SE = 33.5). To understand if translation speed is influenced by any variables, we ran a linear regression analysis with translation speed as the dependent variable and the following predictors: lexical category (noun=1, verb =2), word length (in English), name agreement (English), age of acquisition, cognate status, English frequency and Spanish frequency. These predictors are defined in Experiment 1 and their values were obtained from the IPNP database (Bates et al., 2003). The model was significant ($F(6,181) = 21.8$, $R^2 = .41$, $p < .001$), with lexical category as the only significant predictor ($\beta = -.68$, $p < .0010$). Thus, there do not seem to be other influences on translation speed.

We explored how translation speed was associated with lexical frequency and picture naming speed. Translation speed and lexical frequency (in English) were not correlated for nouns (Pearson $r = -.16$, p =.11) or verbs (Pearson $r = -.15$, p =.15), which was important to determine so that there is no collinearity confound when analyzing frequency and translation speed in the same statistical model (next section). Translation speed was significantly positively correlated with English and Spanish picture naming for both nouns and verbs, even when the effects of frequency were controlled (all bivariate correlations $r > .11$, $p < .01$).

--------------Figures 2 & Table 4----------

Effects of frequency and translatability on picture naming speed

For the main analysis of this experiment, picture naming speed in each language was analyzed separately using a 3-way LME with lexical category (noun, verb), frequency (low, high) and translatability (low, high) as fixed effects and participants, and items as random effects. The intercept was included for both fixed and random effects (Table 5 and Figure 3). In English, there were significant main effects of lexical category (naming times are faster for nouns than verbs), frequency (naming times are faster for high frequency than low frequency words) and translatability (naming times are faster for high translatability than low translatability words). There was also a significant 3-way interaction between lexical category, frequency and translatability, showing that translatability effects are found only for low frequency nouns and high frequency verbs. Two-way interactions between lexical category and frequency/translatability ($p<.05$) showed that frequency and translatability effects were smaller for verbs (mean difference for frequency = 73ms, for translatability = 40ms) than for nouns (mean difference for frequency = 124ms, for translatability = 64ms). Spanish picture naming showed main effects of lexical category (nouns are named faster than verbs) and frequency (faster naming for high frequency words) and a significant 3-way interaction between lexical category, frequency and translatability, showing that translatability effects are found only for low frequency nouns.

--------------Figure 3 & Table 5----------

In sum, high frequency facilitated naming in both lexical categories and both languages; the frequency effect was larger in Spanish (nouns=209ms, verbs =188ms) than in English (nouns = 124ms, verbs = 73ms) and for nouns than for verbs. High translatability facilitated naming of low frequency nouns in English and Spanish and high frequency verbs in English. Spanish picture naming differed from English picture naming in the following ways: 1) there was a larger frequency effect in Spanish compared to English, 2) there was no main effect of translatability, and 3) translatability did not facilitate high frequency verbs. The translation task involved translation from Spanish to English, hence it is not surprising that translation speeds (English names) were more strongly associated with English picture naming RT than with Spanish picture naming RT. The results did not change when only non-cognates were analyzed, and these statistics are provided in the Supplemental file.

Discussion

The primary goal of Experiment 2 was to test two possible explanations for the smaller bilingual verb cost by examining frequency and translatability effects across lexical categories and languages. We found that verbs showed smaller frequency effects and were translated faster than nouns. For all words, translation speed was positively correlated with naming speed.

Frequency effect for verbs and nouns

The finding of a larger frequency effect on picture naming speed in Spanish compared to English is consistent with the classic prediction of the frequency lag/weaker links account that the less dominant language would show stronger frequency effects. Verbs showed smaller frequency effects compared to nouns, which replicates the findings of the regression analyses in Experiment 1. This experiment confirms that frequency has a smaller role on verb naming than it does on noun naming in bilingual speakers, as with monolingual speakers (Bonin et al., 2004; Cuetos & Alija, 2003; Shao et al., 2012; Szekely et al., 2005). This finding, however, is different from Li et al. (2018), who found no difference in the magnitude of frequency effect between nouns and verbs. In fact, Li et al. (2019) did not find a frequency effect for nouns in their monolingual and bilingual speakers' L1, an effect that is typically very robust (Oldfield & Wingfield, 1965). This suggests that their noun stimuli may not have provided a sufficient frequency contrast to elicit a frequency effect. Differences in languages (Mandarin-English vs English-Spanish), participants' age of L2 acquisition, and statistical analyses methods could have also contributed to the different findings between Li et al. (2019) and the present study.

The pattern of smaller frequency effects for verbs compared to across both Experiments indicates that the frequency lag account cannot serve as the sole explanation for bilingual cost, and other factors, particularly lexical category and translatability, need to be considered in explaining bilingual word retrieval.

Translatability of verbs and nouns

For both nouns and verbs, translation speed, which was our measure of cross-language connectivity, was positively correlated with picture naming speed and had a significant main effect on naming, such that low translatabilty words were named more slowly. This is consistent with other studies showing an association between translation speed/accuracy and picture naming speed/accuracy (Gollan et al., 2005; Li et al., 2019). However, it is inconsistent with the basic premise of the cross-language interference/competition account that stronger cross-language connections would trigger greater competition during lexical retrieval resulting in slower naming times.

Translation speed was *faster* for verbs compared to nouns. At minimum, the cognitive demands of the translation task involve the following steps: reading a word, finding a cross-language equivalent, and articulating the translation. The faster verb translation speed couldn't arise from faster reading times for verbs because verbs and nouns were frequency matched, and, in fact, studies have found slower reading (lexical decision) speed for verbs compared to nouns (Kauschke & Stenneken, 2008; Yang et al., 2011). Retrieving the translation could occur through direct lexical links between translation equivalents, especially for low-proficiency bilinguals (per Kroll & Stewart's Revised Hierarchical Model, 1994), or through conceptual mediation (Spanish stimulus>>conceptual representation>>English translation). Irrespective of whether this study's participants accomplished the translation task through direct lexical connections or conceptual mediation, the fact that verbs were translated faster indicates *stronger* cross-language connections between verb translations than between noun translations.

To explain why the bilingual cost is smaller for verbs compared to nouns, we propose that verbs receive an extra activation boost (or facilitation) from their more strongly connected translation, speeding up lexical access. This facilitation is weaker for nouns, especially for high frequency nouns (as evidenced by the interaction between lexical category, frequency and translatability, Table 5). To explain the smaller verb cost in Spanish compared to English in both Experiments, we further propose that the less dominant language (Spanish in our study) benefits more from this cross-language translation facilitation than the dominant language. Other potential reasons for a smaller bilingual verb cost that were not tested in this study are discussed under General Discussion.

We now revisit the initial assumption of weaker cross-language connections for verbs to reconcile our findings with the limited evidence available (Prior et al., 2007; 2013; van Hell &

DeGroot, 1998). One study used a double-translation task, in which a paragraph is translated from English to another language, and a new speaker translated the other-language translation back into English (Gentner, 1981). When the original and double-translated English versions were compared, there were fewer verbs than nouns in common. Another study counted the number of within-language and between-language word associations that were translations (van Hell & DeGroot, 1998), and found a marginally lower number of such translations for verbs (28%) than for nouns (30.9%). This difference was significant by participants (F1) but not by items (F2). Prior et al. (2007) counted the number of different translations produced for each stimulus in a written translation task and found that a larger number of verbs (55-57%) produced more than one translation than nouns did (42-45%). The number of translations was predicted by imageability, frequency, cognate status, lexical category and word class ambiguity. A later study examined the probability that a translation will be used and found an influence of word length, imageability, and cognate status, but not lexical category (Prior et al., 2012). Across these small number of studies, it appears that while verbs produce a wider variety of translations, this can be attributed to other factors that tend to differ between nouns and verbs, and not to lexical category membership per se. As for translation speed across lexical categories, the only comparison is with Li et al. (2019), who did not report a direct statistical comparison between verb and noun translation speed, and found no significant interaction between translation speed and word category (Table 3 in Li et al., 2019). The direction of translation (non-dominant to dominant) was the same in both studies. However, as mentioned earlier, there were some differences in participant characteristics and methods (especially noun stimuli and statistical approaches) across the two studies. This highlights the importance of replicating the findings of the current study with further research into lexical category differences.

In summary, we found that 1) frequency effects are smaller for verbs compared to nouns, showing the limits of the frequency lag/weaker links account, and 2) translatability is positively associated with word naming speed, showing the untenability of the cross-language interference account. Based on the faster translation speeds of verbs, we suggest that verbs may receive a stronger facilitation from their translations than nouns, probably accounting for the smaller bilingual cost for verbs compared to nouns. It should be noted, further, that translation effects interact in complex ways with frequency and lexical category, as these are found in specific instances (low frequency nouns and high frequency verbs).

General discussion

The main purpose of this study was to examine verb naming in bilinguals within the context of current accounts of bilingual lexical organization. In the following paragraphs, we discuss the general differences across lexical categories, the magnitude of verb cost in bilinguals, and implications for models of bilingual lexical organization. But first, we point out cautions in interpreting the findings of this study. Findings from a picture naming task may have limited generalizability to the cognitive processes that occur in natural bilingual communication, particularly with reference to retrieval of verbs in sentence contexts and of non-imageable nouns and verbs. Translations were elicited in a single direction (non-dominant-to-dominant language), and thus lexical category differences in translation speed may need further replication.

Differences between verbs and nouns

Across both experiments, verb naming was slower than noun naming, consistent with prior monolingual (Haman et al., 2017; Kauschke & Frankenberg, 2008; Shao et al., 2012; Szekely et al., 2005) and bilingual findings (Hernandez et al., 2008; Kambanaros, Grohmann &

Michaelides, 2013; Li et al., 2019). This is remarkable given that verbs had overall higher usage frequency and were shorter in length than nouns in Experiment 1 (Szekely et al., 2005), and were matched for frequency in Experiment 2. As is evident from the name agreement scores in Table 2, both monolinguals and bilinguals produced a wider variety of names for action pictures than for object pictures. Action pictures may have lower name agreement because participants may be selecting among a larger number of alternate names (sleep/nap/lay/dream vs. bed, eat/bite/chew vs. apple). This increased need for resolution among more responses may increase processing time, resulting in longer verb naming times. To understand why action pictures would activate a larger number of alternate names than object pictures, we need to consider the components of picture naming. At minimum, these include basic visual processing, object recognition, scene analysis (especially for actions), activation of target lexical representations (in the target language), selection among lexical representations, phonological and articulatory planning (Indefrey & Levelt, 2004). Action scenes, like "driving" in Figure 4, not only entail recognition of multiple entities (man, steering wheel, placement of hands etc.), but also drawing inferences about the relationships among these entities to generate the possible action name. The regression analysis results in Experiment 1 are consistent with the idea that both name agreement and conceptual complexity (i.e., number of items in the picture) influence picture naming speed (Table 3). Additionally, verb naming times could be longer because verbs activate thematic role knowledge, such as knowledge of typical agents (arresting-cop), patients (arresting-criminal), instruments (stirring-spoon), and features of their patients (manipulating-naive) (Ferretti, McRae & Hatherell, 2001). Evidence for the influence of thematic role knowledge on verb naming times comes from longer latencies for transitive compared to intransitive verbs (Kauschke & Frankenberg, 2008). In sum, there are numerous reasons that could increase verb naming times, particularly greater perceptual/event recognition times and greater name ambiguity (Prior et al., 2007). These additional influences on verb naming could also account for the diminished influence of word frequency on verb naming speed, as was evident in both experiments in this study with bilinguals, and in prior research with monolinguals (Bonin et al., 2004; Cuetos & Alija, 2003; Shao et al., 2012; Szekely et al., 2005).

The bilingual cost is smaller for verbs

The intriguing aspect of verb naming latencies is that their slowdown as a function of bilingual status (Experiment 1, Li et al., 2019) and L2 status (Experiments 1 and 2; Li et al., 2019) is smaller compared to the slowdown observed for nouns. Our investigation targeted translatability and frequency effects. The faster translation speeds for verbs compared to nouns suggest stronger cross-language connections and stronger facilitation by translations for verb retrieval. This explains the smaller verb cost in picture naming. Across both experiments, verbs had smaller frequency effects even though verb frequencies were matched (Experiment 2) or higher than (Experiment 1) noun frequencies. The frequency lag hypothesis does not provide a satisfactory explanation of smaller verb frequency effects. The current study thus identifies the limitations of frequency effects on bilingual language processing (Gollan et al., 2011; Sadat et al., 2016).

There are possibly other factors that influence how words from each lexical category are retrieved, and this needs further experimentation. For example, there is some evidence that verbs may rely to a greater extent on cognitive control than nouns (Shao et al., 2012; Silveri & Ciccarelli, 2007). Although the extent to which bilinguals and monolinguals differ in their reliance on domain general cognitive control mechanisms during lexical retrieval is still unclear (Bialystok, Craik & Luk, 2008; Faroqi-Shah, Sampson, Pranger, & Baughman, 2018), it is plausible that bilingualism, verbs and cognitive control interact to yield a smaller bilingual cost for verbs. Second, the regression analyses in Table 3 (a and b) show that conceptual complexity, which is higher in verbs, exerts a smaller influence on bilingual naming times (compared to monolinguals), and this could potentially contribute to a smaller bilingual verb cost. Third, there could be simultaneous cross-language interference effects at play, especially for nouns. Cook and Gor (2015) found that words with more robust phonological-lexical representations (as determined by a translation rating task) were more likely to show cross language interference effects in a lexical decision task. Finally, picture naming of verbs is much slower than that of nouns due to a variety of reasons as discussed in the previous section (in monolinguals and bilinguals). This could place limits on how much more slower bilinguals could name verb pictures (a ceiling effect), thus diminishing the magnitude of the verb cost.

Implications for models of bilingual lexical representation

The classic model of bilingual lexical representation (Kroll & Stewart, 1994) proposed two distinct lexicons for L1 and L2. This assumption of language-specific lexicons has been challenged by numerous findings whose discussion is beyond the scope of this paper (see reviews in Basnight-Brown, 2014; Brysbaert & Duyck, 2010; Dijkstra et al., 2019; Dong, Gui & MacWhinney, 2005; and examples of recent evidence in Dylman & Barry, 2018; Ibrahim et al., 2017). Based on the strength of this evidence, we assume an integrated lexicon that houses lexical representations for both languages.

In Figure 4, starting with Dylman and Barry's (2018) framework of a shared bilingual lexicon, we integrate what is currently known about verb and noun retrieval in bilinguals to propose how these might be organized in the mental lexicon. The *Bilingual Integrated Grammatical Category (BIGC) model* in Figure 4 represents lexical organization in highly proficient bilingual speakers like those of the present study. We use low and high frequency verbs and nouns as examples to illustrate frequency effects. We use a lemma tier (instead of "semantic features") to incorporate syntactic information inherent to verb representations. Connections between verbs and their arguments (drive-truck) are represented with dotted lines, the evidence for which comes from priming paradigms (Ferretti et al., 2001). Within the lexical-phonological tier, higher frequency nouns (camion, truck) have a higher baseline activation level (Dijkstra et al., 2019) as illustrated by the bold font, causing them to be retrieved faster than lower frequency nouns. This frequency difference is not depicted for verbs given that they are less influenced by frequency. The stronger cross-language connections of verb representations, which account for their faster translation speeds, are represented with thicker lines between verb translations (conducer-driving, patinar-skating). There would also be stronger lexical connections between cognates, which are not represented in Figure 4 for simplicity. The shaded region around verbs denotes a lexical separation between verbs and nouns, based on evidence of verb-noun double dissociations in bilinguals (Faroqi-Shah & Waked, 2010, Kambanaros and van Steenbrugge, 2006) and monolinguals (Caramazza & Hillis, 1991) with brain injury.

------------Figure 4------------

Conclusions

The first Experiment highlighted the role of conceptual (age of acquisition, name agreement), perceptual (picture complexity), and articulatory (initial frication and word length) factors in picture naming speed, in addition to bilingual status and lexical category. Further examination of the latter two variables across two experiments provided converging evidence that the bilingual cost was smaller for verb naming than it was for noun naming (consistent with Li et al., 2019). Lexical frequency exerted a smaller effect on verb naming than it did on noun naming. Verbs were also translated faster than nouns, despite their longer picture naming times. The smaller bilingual cost for verbs is explained by stronger cross-language connections between verb translations, which facilitates their retrieval and partially offsets the bilingual cost. Noun retrieval, in contrast, is more dependent on usage frequency. Thus, the frequency lag account better explains noun retrieval, and a cross-language facilitation from translations better explains verb retrieval.

This study illustrates the limits of lexical frequency on word retrieval. The absence of cross-language interference from translation equivalents, as measured by the association between translation and picture naming speed, questions the assumption that the lexical representations of the two languages of a bilingual compete during language production (Green, 1998; Hall, 2011; Lee & Williams, 2001; Sandoval et al., 2010; Van Hell & de Groot, 1998), although a bilingual might require extra cognitive effort to maintain a single output language. To conclude, the present study highlights the importance of diversifying the kinds of words that are used to investigate the intricacies of bilingual lexical representation, particularly by including verbs.

References

Baayen, R. H., Davidson, D. J., & Bates, D. M. (2008). Mixed-effects modeling with crossed random effects for subjects and items. *Journal of Memory and Language, 59*(4), 390-412.

Baayen, R., Piepenbrock, R., & van Rijn, H. (1993). The CELEX lexical database (Release 1) [CD-ROM]. Phildelphia, Linguistic Data Consortium: University of Pennsylvania [Distributer].

Basnight-Brown, D. M. (2014). Models of Lexical Access and Bilingualism. In R. R. Heredia & J. Altarriba (Eds.), *Foundations of Bilingual Memory* (pp. 85-107). New York, NY: Springer New York.

Bates, E., Andonova, E., D'amico, S., Jacobsen, T., Kohnert, K., Lu, C. C., ... & Iyer, G. (2000). 12(1), 12-1. (2000). Introducing the CRL international picture-naming project (CRL-IPNP). *Center for Research in Language Newsletter, 12*(1), 12.

Bates, E., D'Amico, S., Jacobsen, T., Szekely, A., Andonova, E., Devescovi, A., . . . Tzeng, O. (2003). Timed picture naming in seven languages. *Psychonomic Bulletin & Review, 10*, 344-380.

Bialystok, E., Craik, F. I. M., & Luk, G. (2008). Lexical access in bilinguals: Effects of vocabulary size and executive control. Journal of Neurolinguistics, 21(6), 522-538. doi:http://dx.doi.org/10.1016/j.jneuroling.2007.07.001

Birdsong, D., Gertken, L. M., & Amengual, M. (2012). Bilingual Language Profile: An Easy-to-Use Instrument to Assess Bilingualism. Retrieved 08 April, 2012, from COERLL, University of Texas at Austin https://sites.la.utexas.edu/bilingual/

Bonin, P., et al. (2004). Psycholinguistic norms for action photographs in French and their relationships with spoken and written latencies. *Behavior Research Methods, Instruments, & Computers, 36(1*), 127-139.

Brysbaert, M., & New, B. (2009). Moving beyond Kucera and Francis: a critical evaluation of current word frequency norms and the introduction of a new and improved word frequency measure for American English. *Behavior Research Methods, 41*(4), 977-990. doi: 10.3758/brm.41.4.977

Bylund, E., Abrahamsson, N., Hyltenstam, K., & Norrman, G. (2019). Revisiting the bilingual lexical deficit: The impact of age of acquisition. *Cognition, 182*, 45-49. doi: https://doi.org/10.1016/j.cognition.2018.08.020

Caramazza, A., & Hillis, A. E. (1991). Lexical organization of nouns and verbs in the brain. Nature, 349(6312), 788-790.

Cook. S., & Gor, K. (2015). Lexical access in L2. *The Mental Lexicon, 10*(2), 247-270. doi:10.1075/ml.10.2.04

Costa, A., Miozzo, M., & Caramazza, A. (1999). Lexical Selection in Bilinguals: Do Words in the Bilingual's Two Lexicons Compete for Selection?*, 41*(3), 365.

Costa, A., Santesteban, M., & Cano, A. (2005). On the facilitatory effects of cognate words in bilingual speech production. *Brain and Language, 94*, 94-103.

Cuetos, F., & Alija, M. (2003). Normative data and naming times for action pictures. *Behavior Research Methods, Instruments & Computers, 35*(1), 168-177. doi:10.3758/BF03195508

Cuetos, F., Glez-Nosti, M., Barbon, A., & Brysbaert, M. (2011). SUBTLEX-ESP: Spanish word frequencies based on film subtitles. *Psicologica, 32*, 133-143.

de Groot, A. M. (1992). Determinants of word translation. Journal of Experimental Psychology: Learning, Memory, and Cognition, 18(5), 1001-1018. doi: 10.1037/0278-7393.18.5.1001

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.

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.

Degani, T., Prior, A., Eddington, C. M., Arêas da Luz Fontes, A. B., & Tokowicz, N. (2016). Determinants of translation ambiguity: A within and cross-language comparison. *Linguist Approaches Biling, 6*(3), 290-307. doi:https://doi.org/10.1075/lab.14013.deg

Diependaele, K., Lemhofer, K., & Brysbaert, M. (2013). The word frequency effect in first- and second-language word recognition: a lexical entrenchment account. *Q J Exp Psychol (Hove), 66*(5), 843-863. doi: 10.1080/17470218.2012.720994

Dijkstra, T. O. N., Wahl, A., Buytenhuijs, F., Van Halem, N., Al-Jibouri, Z., De Korte, M., & RekkÉ, S. (2019). Multilink: a computational model for bilingual word recognition and word translation. *Bilingualism: Language and Cognition, 22*(4), 657-679. doi:10.1017/S1366728918000287

Dijkstra, T., & Van Heuven, W. J. B. (2002). The architecture of the bilingual word recognition system: From identification to decision. *Bilingualism: Language and Cognition, 5*(3), 175-197.

Dong, Y., Gui, S., & MacWhinney, B. (2005). Shared and Separate Meanings in the Bilingual Mental Lexicon. *Bilingualism: Language and C o g n i t i o n, 8*(3), 221-238.

Duyck, W., Vanderelst, D., Desmet, T., & Hartsuiker, R. J. (2008). The frequency effect in second-language visual word recognition. *Psychonomic Bulletin and Review, 15*(4), 850-855.

Dylman, A. S., & Barry, C. (2018). When having two names facilitates lexical selection: Similar results in the picture-word task from translation distractors in bilinguals and synonym distractors in monolinguals. *Cognition, 171*, 151-171. doi: 10.1016/j.cognition.2017.09.014

Ellis, A. W., & Lambon Ralph, M. A. (2000). Age of acquisition effects in adult lexical processing reflect loss of plasticity in maturing systems: Insights from connectionist networks. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 26*(5), 1103-1123. doi:10.1037/0278-7393.26.5.1103

Ellis, A. W., & Morrison, C. M. (1998). Real age-of-acquisition effects in lexical retrieval. *Journal Experimental Psychology Learning, Memory and Cognition, 24*(2), 515-523.

Faroqi-Shah, Y., & Waked, A. (2010). Grammatical category dissociation in multilingual aphasia. *Cognitive Neuropsychology, 27*, 181-203. doi: 10.1080/02643294.2010.509340

Faroqi-Shah, Y., Sampson, M., Pranger, M., & Baughman, S. (2018). Cognitive control, word retrieval and bilingual aphasia: Is there a relationship? Journal of Neurolinguistics, 45, 95-109. doi:https://doi.org/10.1016/j.jneuroling.2016.07.001

Fenson, L., Dale, P., Reznick, J., Bates, E., Thal, D., & Pethick, S. (1994). Variability in early communicative development. *Monographs of the Society for Research in Child Development, Serial No. 242, 59*(5).

Ferretti, T. R., McRae, K., & Hatherell, A. (2001). Integrating Verbs, Situation Schemas, and Thematic Role Concepts. *Journal of Memory and Language, 44*(4), 516-547. doi: https://doi.org/10.1006/jmla.2000.2728

Forster, K. I., & Forster, J. C. (2003). DMDX: A windows display program with millisecond accuracy. *Behavior Research Methods, Instruments, & Computers, 35*, 116-124.

Gentner, D. (1981). Some interesting differences between nouns and verbs. *Cognition and Brain Theory, 4*, 161-178.

Gentner, D. (1982). Why nouns are learned before verbs: linguistic relativity versus natural partitioning. In S. Kucszaj (Ed.), *Language Development* (Vol. 2: Language, thought and culture, pp. 301-334). Hillsdale, N.J.: Lawrence Erlbaum.

Gollan, T. H., & Acenas, L. A. (2004). What is a TOT? Cognate and translation effects on tip-of-the-tongue states in Spanish–English and Tagalog–English bilinguals. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 30*, 246–269.

Gollan, T. H., Bonanni, M. P., & Montoya, R. I. (2005). Proper names get stuck on bilingual and monolingual speakers' tipof- the-tongue equally often. *Neuropsychology, 19*, 278–287.

Gollan, T. H., Montoya, R. I., Fennema-Notestine, C., & Morris, S. K. (2005). Bilingualism affects picture naming but not picture classification. *Memory and Cognition, 33*(7), 1220-1234.

Gollan, T. H., Slattery, T. J., Goldenberg, D., Van Assche, E., Duyck, W., & Rayner, K. (2011). Frequency drives lexical access in reading but not in speaking: The frequency-lag hypothesis. *Journal of Experimental Psychology: General, 140*(2), 186-209. doi: 10.1037/a0022256

Grainger, J. (1993). Visual word recognition in bilinguals. *The bilingual lexicon.* (pp. 11-25). Amsterdam, Netherlands: John Benjamins Publishing Company.

Green, D. (1998). Mental Control of the Bilingual Lexico-semantic system. *Bilingualism: Language and Cognition, 1*, 67-81.

Hall, M. L. (2011). Bilingual picture-word studies constrain theories of lexical selection. *Frontiers in Psychology, 2*, 381. doi: 10.3389/fpsyg.2011.00381

Haman, E., Luniewska, M., Hansen, P., Simonsen, H. G., Chiat, S., Bjekic, J., . . . Armon-Lotem, S. (2017). Noun and verb knowledge in monolingual preschool children across 17 languages: Data from cross-linguistic lexical tasks (LITMUS-CLT). *Clinical Linguistics & Phonetics*, 1-26. doi: 10.1080/02699206.2017.1308553

Hermans, D., Bongaerts, T., de Bot, K., & Schreuder, R. (1998). Producing words in a foreign language: Can speakers prevent interference from their first language?. *Bilingualism: Language and Cognition, 1*, 213–229.

Hernandez, M., Cano, A., Costa, A., Sebastian-Galles, N., Jucandella, M., & Gascon-Bayarri, J. (2008). Grammatical category -specific deficits in bilingual aphasia. *Brain and Language, 107*, 68-80.

Ibrahim, A., Cowell, P. E., & Varley, R. A. (2017). Word frequency predicts translation asymmetry. *Journal of Memory and Language, 95*, 49-67. doi: 10.1016/j.jml.2017.02.001

Indefrey, P., & Levelt, W. J. M. (2004). The spatial and temporal signatures of word production components. *Cognition, 92*(1), 101.

Ivanova, I., & Costa, A. (2008). Does bilingualism hamper lexical access in speech production? *Psychologica, 127*, 277-288.

Kambanaros, M., & van Steenbrugge, W. (2006). Noun and verb processing in Greek-English bilingual individuals with anomic aphasia and the effect of instrumentality and verb-noun name relation. Brain and Language, 97(2), 162-177. doi:10.1016/j.bandl.2005.10.001

Kambanaros, M., Grohmann, K. K., & Michaelides, M. (2013). Lexical retrieval for nouns and verbs in typically developing bilectal children. *First Language, 33*(2), 182-199. doi: 10.1177/0142723713479435

Kauschke, C., & von Frankenberg, J. (2008). The differential influence of lexical parameters on naming latencies in German. A study on noun and verb picture naming. *J Psycholinguist Res, 37*(4), 243-257. doi: 10.1007/s10936-007-9068-5

Klassert, A., Gagarina, N., Kauschke, C. (2014). Object and action naming in Russian- and German- speaking monolingual and bilingual children. *Bilingualism: Language and Cognition, 17*(1), 73-88.

Kohnert, K. J., Bates, E., & Hernandez, A. E. (1999). Balancing Bilinguals Lexical-Semantic Production and Cognitive Processing in Children Learning Spanish and English. *Journal of Speech, Language, and Hearing Research, 42*(6), 1400-1413. doi: 10.1044/jslhr.4206.1400

Kohnert, K. J., Hernandez, A. E., & Bates, E. (1998). Bilingual performance on the Boston naming test: preliminary norms in Spanish and English. *Brain & Language, 65*(3), 422-440.

Kroll, J. F., & Stewart, E. (1994). Category Interference in Translation and Picture Naming: Evidence for Asymmetric Connections Between Bilingual Memory Representations. Journal of Memory and Language, 33(2), 149-174.

Kroll, J. F., Bobb, S. C., Misra, M., & Guo, T. (2008). Language selection in bilingual speech: Evidence for inhibitory processes. *Acta Psychologica, 128*(3), 416-430. doi: http://dx.doi.org/10.1016/j.actpsy.2008.02.001

Kroll, J. F., van Hell, J. G., Tokowicz, N., & Green, D. W. (2010). The Revised Hierarchical Model: A critical review and assessment. *Biling (Camb Engl), 13*(3), 373-381. doi: 10.1017/S136672891000009X

Lachman, R., Shaffer, J. P., & Hennrikus, D. (1974). Language and cognition: Effects of stimulus codability, name-word frequency, and age of acquisition on lexical reaction time. *Journal of Verbal Learning & Verbal Behavior, 13*(6), 613-625. doi:10.1016/S0022-5371(74)80049-6

Lee, M.-W., & Williams, J. N. (2001). Lexical access in spoken word production by bilinguals: evidence from the semantic competitor priming paradigm. *Bilingualism: Language and Cognition, 4*(3), 233-248. doi: 10.1017/S1366728901000426

Lemhöfer, K., & Broersma, M. (2012). Introducing LexTALE: A quick and valid Lexical Test for Advanced Learners of English. *Behavior Research Methods, 44*, 325-343.

Lemhöfer, K., Dijkstra, T., Schriefers, H., Baayen, R. H., Grainger, J., & Zwisterlood, P. (2008). Native language influences on word recognition in a second language: A megastudy. *Journal of Experimental Psychology: Learning, Memory & Cognition, 34*(12-31).

Li, R., Faroqi-Shah, Y., & Wang, M. (2018). A comparison of verb and noun retrieval in Mandarin–English bilinguals with English-speaking monolinguals. *Bilingualism: Language and Cognition*, 1-24. doi: 10.1017/S1366728918000913

Lo, S., & Andrews, S. (2015). To transform or not to transform: using generalized linear mixed models to analyse reaction time data. *Frontiers in Psychology, 6*, 1171-1171. doi: 10.3389/fpsyg.2015.01171

Marian, V., & Spivey, M. (2003). Competing activation in bilingual language processing: Within- and between-language competition. *Bilingualism: Language and Cognition, 6*, 97-115.

Matzig, S., Druks, J., Masterson, J., & Vigliocco, G. (2009). Noun and verb differences in picture naming: Past studies and new evidence. *Cortex, 45*, 738-758.

Misra, M., Guo, T., Bobb, S. C., & Kroll, J. F. (2012). When bilinguals choose a single word to speak: Electrophysiological evidence for inhibition of the native language. *Journal of Memory and Language, 67*(1), 224-237. doi: http://dx.doi.org/10.1016/j.jml.2012.05.001

Morrison, C. M., Hirsh, K. W., & Duggan, G. B. (2003). Age of acquisition, ageing, and verb production: Normative and experimental data. *The Quarterly Journal of Experimental Psychology Section A, 56*(4), 705-730.

O'Grady, W. (1997). *Syntactic Development*. Chicago: Chicago Univeristy Press.

Oldfield, R. C., & Wingfield, A. (1965). Response latencies in naming objects. *Quarterly Journal of Experimental Psychology, 17*, 273-281.

Palmer, S. D., & Havelka, J. (2010). Age of acquisition effects in vocabulary learning. Acta Psychologica, 135(3), 310-315. doi: http://dx.doi.org/10.1016/j.actpsy.2010.08.002

Prior, A., Kroll, J. F., & Macwhinney, B. (2012). Translation ambiguity but not word class predicts translation performance. *Bilingualism: Language and Cognition, 16*(2), 458-474. doi: 10.1017/S1366728912000272

Prior, A., MacWhinney, B., & Kroll, J. F. (2007). Translation norms for English and Spanish: The role of lexical variables, word class, and L2 proficiency in negotiating translation ambiguity. *Behavior Research Methods, 39*, 1029–1038.

Sadat, J., Martin, C. D., Magnuson, J. S., Alario, F. X., & Costa, A. (2016). Breaking Down the Bilingual Cost in Speech Production. *Cognitive Science, 40, 1911-1940*. doi: 10.1111/cogs.12315

Sandoval, T. C., Gollan, T., Ferreira, V. S., & Salmon, D. P. (2010). What causes the bilingual disadvantage in verbal fluency? The dual-task analogy. *Bilingualism: Language and Cognition, 13*(02), 231-252. doi: doi:10.1017/S1366728909990514

Shao, Z., Roelofs, A., & Meyer, A. S. (2012). Sources of individual differences in the speed of naming objects and actions: The contribution of executive control. *The Quarterly Journal of Experimental Psychology, 65*(10), 1927-1944. doi: 10.1080/17470218.2012.670252

Sullivan, M. D., Poarch, G. J., & Bialystok, E. (2018). Why is lexical retrieval slower for bilinguals? Evidence from picture naming. *Bilingualism: Language and Cognition, 21*(3), 479-488. doi: 10.1017/S1366728917000694

Swender, E., Conrad, D., & Vicars, R. (2012). ACTFL proficiency guidelines 2012. Retrieved from www.actfl.org website:

Szekely, A., D'Amico, S., Devescovi, A., Federmeier, K., Herron, D., Iyer, G., . . . Bates, E. (2005). Timed Action and Object Naming. *Cortex, 41*(1), 7-25.

van Hell, J. G., & de Groot, A. M. B. (1998). Conceptual representation in bilingual memory: Effects of concreteness and cognate status in word association. *Bilingualism: Language and Cognition, 1*(3), 193-211.

Warrington, E. K., & Shallice, T. (1984). Category specific semantic impairments. *Brain, 107*, 829-853.

Wolff, P., & Ventura, T. (2009). When Russians learn English: How the semantics of causation may change. *Bilingualism: Language and Cognition, 12*(02), 153-176. doi: doi:10.1017/S1366728909004040.

Figure Captions

Figure 1. Bilingual and monolingual picture naming times for nouns and verbs in Experiment 1. The monolingual data are from Szekely et al. (2005). Error bars indicate standard error of the mean. *** = p-value < .001; * = p-value < .05.

Figure 2. Bilingual picture naming and translation times for nouns and verbs in Experiment 2. Error bars indicate standard error of the mean. Translations were from Spanish to English. p-values: *** < .001; ** >.01; * < .05.

Figure 3. Bilingual picture naming showing the interaction between frequency and translatability for nouns (a) and verbs (b). Error bars indicate standard error of the mean. p-values: *** < .001; ** >.01; * < .05.

Figure 4. Illustration of processes involved in picture naming (A, B) and translation (C) of nouns and verbs in highly proficient bilingual speakers. Dotted lines represent connections between verbs and their thematic roles, solid lines represent cross-language connections between translations, with thicker lines (between verbs) representing stronger connections. High frequency nouns have a higher activation level, represented by bold font (camion, truck). The “C” system (from Dylman & Barry, 2018) refers to the cognitive control mechanism that controls the language in which to speak.

Table 1. Demographic information of participants in Experiments 1 and 2 from responses to the Bilingualism Language Profile (Birdsong et al., 2012).

	Experiment 1		*Experiment 2*	
	Mean	SD (range)	Mean	SD (range)
Age (years)	20.2	1.8 (18024)	21	3.2 (18- 30)
Education (years)	14.6	1.2 (14 -17)	15	1.7 (12-19)
Age of exposure to English (years)	2.2	2.9 (0 – 10)	4.3	2.6 (0-6)
Age of exposure to Spanish (years)	4.6	5.6 (0-11)	birth	-
Self-rated proficiency of English (1-6)	5.9	0.24 (5-6)	5.9	0.5 (5-6)
Self-rated proficiency of Spanish (1-6)	5	1.3 (3-6)	5	0.7 (4-6)
Language Dominance	61	26.5 (15- 108)	32.3	38.3 (-66–115)
Percent weekly use of English with friends	64.7%	29.3 (50-100)	91%	13.3 (50-100)
Percent weekly use of Spanish with friends	28.8%	30 (0-50)	16%	23.7 (0-100)
Percent weekly use of English with family	67.5%	31.8 (0-100)	34%	25.4 (0-80)
Percent weekly use of Spanish with family	32.2%	34.9 (0-100)	61%	29.4 (0-100)

Table 2. Description of naming responses. The monolingual English data are from the International Picture Naming Project (Szekely et al., 2005). On the basis of bilingual self-ratings, English is the dominant language (L1), and Spanish is the less dominant language (L2). Bilingual cost = Monolingual English RT minus Bilingual English RT; L2 cost = Bilingual L2 RT minus Bilingual L1 RT; Verb cost = Bilingual Verb RT minus Bilingual Noun RT

	Nouns			Verbs		
	Bilingual		Monolingual	Bilingual		Monolingual
	English	Spanish	English	English	Spanish	English
Experiment 1						
% Valid Responses	72.1	53.3	96.1	65.2	59.3	93.5
Number of Types	2.4	2.9	3.35	5.4	3.3	5.48
% Name Agreement	80	58.8	85	63.7	47.8	71.3
Naming latency (ms) Mean (SD)	1145.8 (251)	1357.5 (297)	1019 (211)	1365 (352)	1480.3 (308)	1279 (269)
Bilingual cost (ms, English)	126	338		86	201	
L2 cost (ms)		211.7			115.3	
Verb cost (ms)				219.2	122.8	260
Experiment 2 Naming						
% Valid Responses	86	79		78	79	
% Accurate Responses	86	61		72	54	
Naming latency (ms) Mean (SD)	1020 (369)	1154(423)		1285 (467)	1346 (465)	
L2 cost (ms)		134			61	
Verb cost (ms)				265	192	
Experiment 2 Translation						
% Valid Responses	78			74.5		
% Accurate Responses	78.1			76.5		

Translation latency (ms) Mean (SD)	1431 (476)	1130 (334)

Table 3. Predictors of English action and object naming times. The values represent unique variance (β) in the last step of the stepwise regression model. The numbers in parentheses are the total variance of the model (R^2). The monolingual English data are from the International Picture Naming Project (Tables 10 & 13 in Szekely et al., 2005).

a. Model I. Separate regression models for nouns and verbs

	Nouns		Verbs	
Predictors	**Bilingual** (.114***)	**Monolingual** (.205***)	**Bilingual** (.069*)	**Monolingual** (.154***)
Length in characters	0.145*	ns	ns	.018*
Initial Frication	ns	ns	ns	ns
Ln Frequency	-0.116*	-0.038***	ns	.016*
Objective AOA (CDI)	0.184***	0.073***	0.159**	0.039**
Obj. Vis. Complexity	ns	-0.007*	ns	ns
Shared-name Items	0.110*	ns	0.131*	.035***
Complex words	ns	ns	ns	ns
Conceptual complexity	ns	0.008*	.122*	.021*

b. Model II. Single regression model adding grammatical category and name agreement to model I

Predictors	**Bilingual** (.284**)	**Monolingual** (.567***)
Length in characters	0.084*	0.003**
Initial Frication	ns	0.002~
Ln Frequency	ns	ns
Objective AOA (CDI)	0.110***	0.018***
Obj. Vis. Complexity	ns	ns
Shared-name Items	ns	ns
Complex words	ns	-0.002*
Conceptual complexity	ns	0.005**

Name Agreement	-0.407***	-0.240***
Verb (1) or Noun (2)	-0.187***	-0.019***

c. Model III. Single regression model with bilingualism added to Model II.

Predictors	**Both groups**	**Both groups (non-cognates only)**
	(.48*)	(0.47***)
Length in characters	0.064**	.069**
Initial Frication	0.040*	ns
Ln Frequency	ns	ns
Objective AOA (CDI)	0.138***	.105***
Obj. Vis. Complexity	ns	ns
Shared-name Items	ns	ns
Complex words	ns	ns
Conceptual complexity	0.060*	.082*
Name Agreement	-0.501***	-0.523***
Verb (1) or Noun (2)	0.197***	.148***
Monolingual (1) or Bilingual (2)	0.204***	.216***

(*** = p < .001; ** = p < .01; * = p < .05 level; ~ = p < .1)

Table 4. Results of statistical analyses of picture naming and translation times for Experiment 2. p-values: *** < .001; ** >.01; * < .05.

	Coef β	**SE (β)**	**t**
Picture Naming Speed			
Fixed effects: Language x Lexical Category			
Intercept	1356.9	32.9	41.2***
Lexical category (Verb)	189.3	17.7	41.2***
Language (Spanish)	51.9	16.3	3.2**
Lexical category x Language	85.9	21.4	4***
Translation Speed			
Fixed effect: Lexical Category			
Intercept	1136	32.9	34.5***
Lexical category (Verb)	323	14.9	21.6***

Table 5. Results of the three-way interaction between lexical category, frequency and translatability for picture naming times in Experiment 2. p-values: *** < .001; ** >.01; * < .05.

Fixed effects: lexical category x frequency x translatability	**Coef β**	**SE (β)**	**t**
English			
Intercept	1212.8	39.6	30.6***
Word category (Noun)	-277.3	33.6	-8.2***
Frequency (Low)	183.1	27.4	6.7***
Translatability (Low)	150.4	42.9	3.5***
Word category x Frequency	-99.2	46.1	-2.1*
Word category x translatability	-125.9	55.9	-2.2*
Frequency x translatability	-220.3	58.5	-3.7***
Word category x Frequency x translatability	299.7	76.8	3.9***
Spanish			
Intercept	1252.9	36.7	34.1***
Word category (Noun)	-225.4	36.1	-6.2***
Frequency (High)	-229.3	32.5	7***
Translatability (High)	44.8	47.4	0.95
Word category x Frequency	-86.6	52.1	-1.6
Word category x translatability	19.8	61.5	0.32
Frequency x translatability	-81.2	71.6	-1.1
Word category x Frequency x translatability	212.3	92.9	2.3*

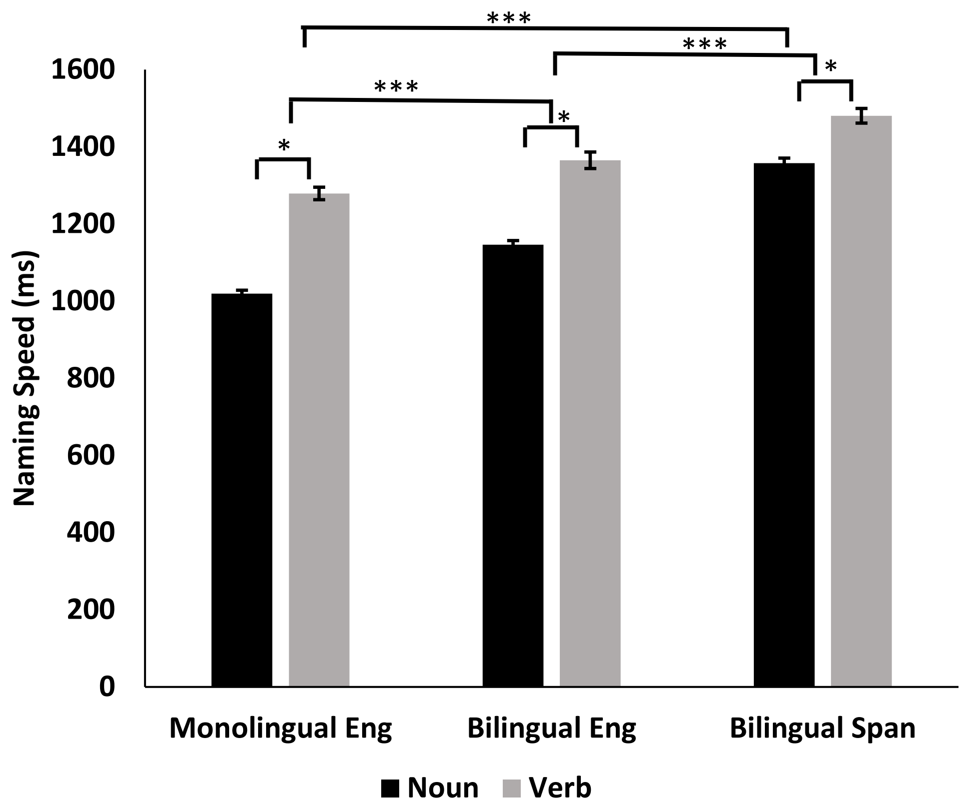


Figure 1. Bilingual and monolingual picture naming times for nouns and verbs in Experiment 1. The monolingual data are from Szekely et al. (2005). Error bars indicate standard error of the mean. *** = p-value < .001; * = p-value < .05.

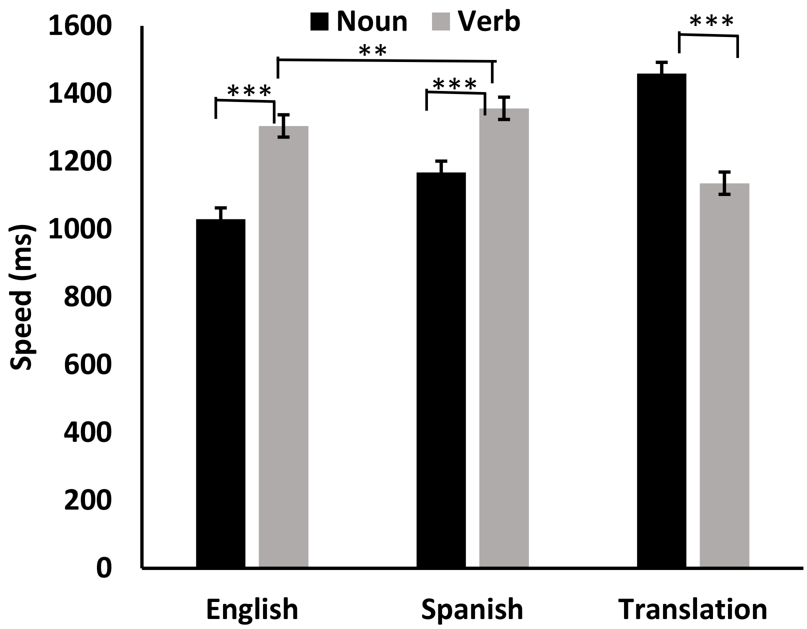


Figure 2. Bilingual picture naming and translation times for nouns and verbs in Experiment 2. Error bars indicate standard error of the mean. Translations were from Spanish to English. p-values: *** < .001; ** >.01; * < .05.

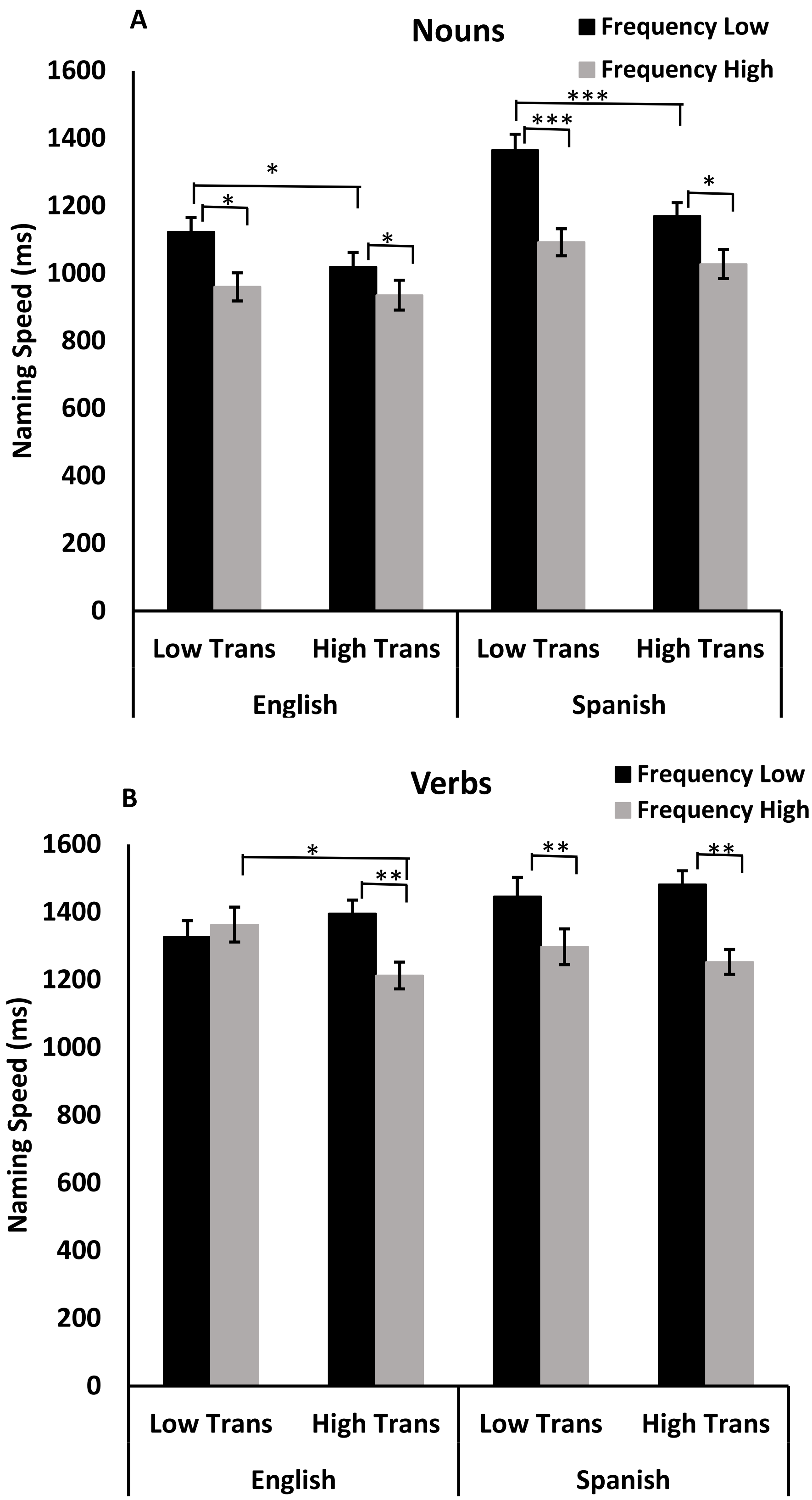


Figure 3. Bilingual picture naming showing the interaction between frequency and translatability for nouns (a) and verbs (b). Error bars indicate standard error of the mean. p-values: *** < .001; ** >.01; * < .05.

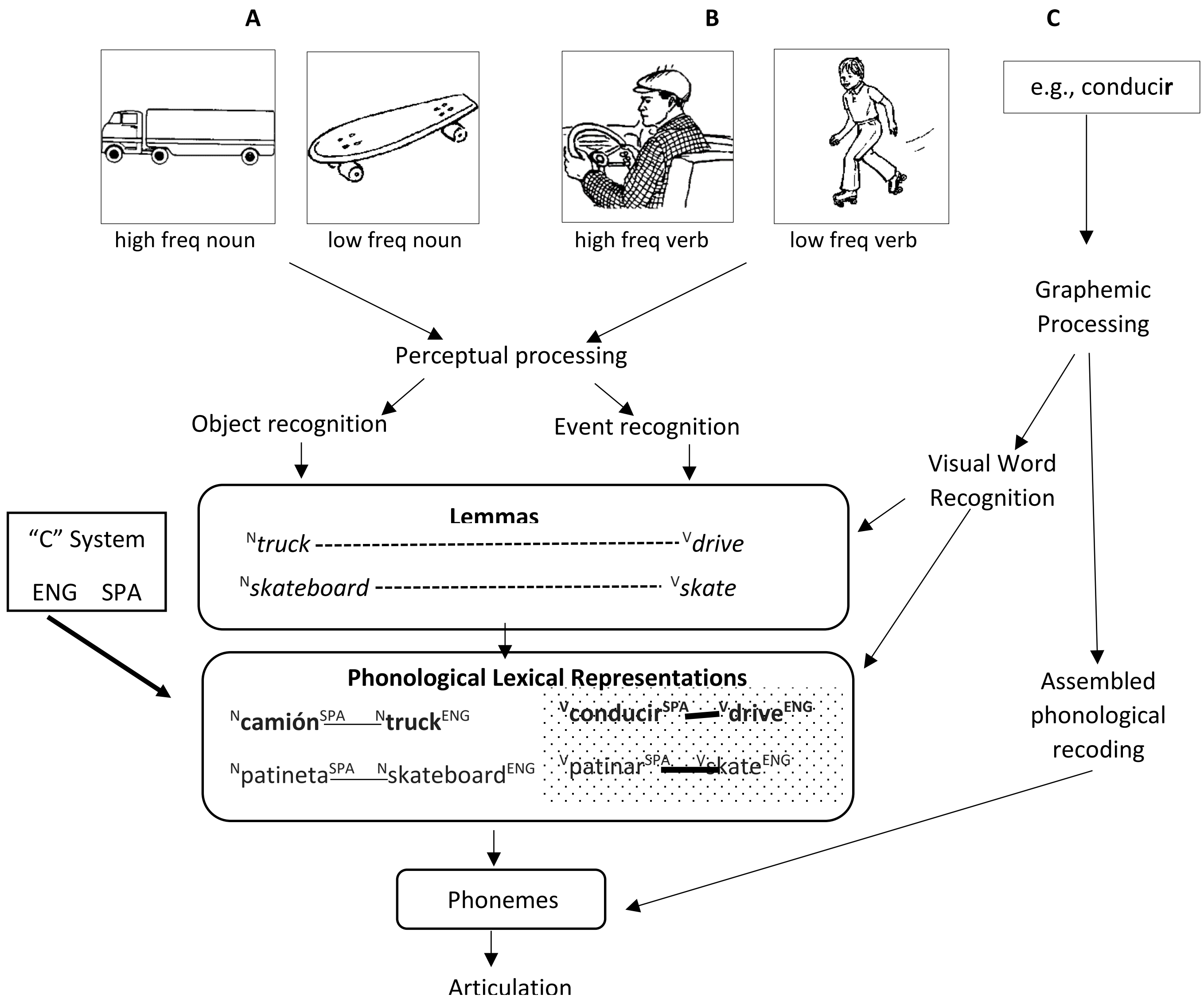

A
B
C
high freq noun
low freq noun
high freq verb
low freq verb
e.g., conducir
Graphemic Processing
Perceptual processing
Object recognition
Event recognition
Visual Word Recognition
Lemmas
Ntruck
Vdrive
Nskateboard
Vskate
"C" System
ENG SPA
Phonological Lexical Representations
NcamiónSPA NtruckENG
VconducirSPA VdriveENG
NpatinetaSPA NskateboardENG
VpatinarSPA VskateENG
Assembled phonological recoding
Phonemes
Articulation

Figure 4. Illustration of processes involved in picture naming (A, B) and translation (C) of nouns and verbs in highly proficient bilingual speakers. Dotted lines represent connections between verbs and their thematic roles, solid lines represent cross-language connections between translations, with thicker lines (between verbs) representing stronger connections. High frequency nouns have a higher activation level, represented by bold font (camion, truck). The “C” system (from Dylman & Barry, 2018) refers to the cognitive control mechanism that controls the language in which to speak.

SUPPLMENT

LEXICAL CATEGORY DIFFERENCES IN BILINGUAL PICTURE NAMING:

IMPLICATIONS FOR MODELS OF LEXICAL REPRESENTATION

Supplementary Table 1. Stimuli used in Experiment 2

IPNP ID	English name	English log freq/million	Spanish name	Spanish log freq/million
Low Frequency Nouns				
obj007	antlers	-0.04	cuernos	2.44
obj010	fishtank	-0.10	pecera	1.81
obj035	beard	1.14	barba	2.75
obj063	broom	0.73	escoba	2.28
obj067	butterfly	0.87	mariposa	2.45
obj085	castle	1.33	castillo	2.95
obj087	celery	0.29	apio	1.77
obj102	clown	1.34	payaso	2.92
obj116	cross	1.36	cruz	2.95
obj117	crown	1.13	corona	2.74
obj130	dolphin	0.84	delfín	2.14
obj147	eskimo	0.18	esquimal	1.71
obj151	feather	1.10	pluma	2.66
obj155	fireman	0.71	bombero	2.43
obj160	flashlight	0.85	lámpara	2.63
obj191	brush	0.87	cepillo	2.60
obj193	hammer	1.07	martillo	2.70
obj221	jar	1.02	frasco	2.54
obj223	jumprope	-0.19	cuerda	2.99
obj232	ladle	-0.09	cucharón	1.34
obj235	lawnmower	0.24	podadora	1.38
obj258	mask	1.39	máscara	2.92
obj264	mixer	0.16	batidora	1.34
obj275	mushroom	0.70	hongo	2.12
obj286	octopus	0.29	pulpo	1.91
obj295	palmtree	0.21	palmera	1.71
obj318	piggybank	-0.13	alcancía	1.48
obj325	pitchfork	-0.07	trinche	0.70
obj332	popcorn	0.87	palomitas	2.52
obj333	popsicle	0.31	paleta	2.01
obj344	raccoon	0.29	mapache	2.03
obj362	rollingpin	-0.70	rodillo	1.43
obj372	sailboat	0.26	velero	1.88
obj379	scarf	0.68	bufanda	2.23
obj380	scissors	0.83	tijeras	2.46
obj395	shovel	0.87	pala	2.43
obj398	skateboard	0.31	patineta	1.92
obj403	sled	-0.74	trineo	2.25
obj416	spider	1.17	araña	2.80
obj421	statue	1.10	estatua	2.67

obj441	teapot	-0.02	cafetera	2.11
obj451	thimble	-0.47	dedal	1.08
obj459	tomato	1.02	tomate	2.62
obj481	unicycle	-0.66	monociclo	0.48
obj482	vacuum	0.73	aspiradora	2.31
obj484	vest	0.83	chaleco	2.50
obj502	wheat	0.76	trigo	2.32
obj504	wheelbarrow	-0.17	carretilla	1.88
obj509	windmill	0.24	molino	2.12
obj514	wolf	1.39	lobo	3.00

High Frequency Nouns

obj011	arm	2.10	brazo	3.37
obj022	bag	2.09	bolsa	3.49
obj037	bed	2.30	cama	3.87
obj048	boat	2.04	barco	3.55
obj049	bomb	1.80	bomba	3.52
obj053	bottle	1.81	botella	3.25
obj056	box	2.01	caja	3.67
obj062	bridge	1.69	puente	3.23
obj065	bus	1.88	camión	3.42
obj071	cake	1.71	pastel	3.36
obj073	camera	1.88	cámara	3.62
obj086	cat	1.94	gato	3.35
obj089	chair	1.77	silla	3.36
obj090	cheese	1.61	queso	3.29
obj095	church	1.86	iglesia	3.54
obj097	city	2.26	ciudad	4.04
obj127	doctor	2.48	doctor	3.88
obj128	dog	2.40	perro	3.84
obj132	door	2.52	puerta	4.14
obj135	dress	1.87	vestido	3.53
obj153	finger	1.85	dedo	3.28
obj154	fire	2.23	fuego	3.74
obj162	floor	2.04	piso	3.62
obj166	foot	2.28	pie	3.63
obj177	ghost	1.71	fantasma	3.21
obj189	gun	2.44	pistola	3.37
obj190	hair	2.21	cabello	3.48
obj195	hand	2.70	mano	4.03
obj201	heart	2.43	corazón	4.02
obj211	horse	2.13	caballo	3.41
obj226	king	2.13	rey	3.68
obj237	leg	2.06	pierna	3.33

obj240	letter	2.09	carta	3.58
obj267	moon	1.72	luna	3.44
obj278	neck	1.80	cuello	3.37
obj283	nose	1.88	nariz	3.35
obj342	queen	1.78	reina	3.41
obj345	radio	1.90	radio	3.49
obj355	ring	1.93	anillo	3.40
obj391	boat	2.04	barco	3.55
obj392	shirt	1.75	camisa	3.28
obj413	soldier	1.83	soldado	3.35
obj431	sun	1.85	sol	3.56
obj437	table	2.08	mesa	3.66
obj447	tv	2.02	televisión	3.38
obj467	train	1.94	tren	3.47
obj469	tree	1.99	árbol	3.34
obj472	truck	1.93	camión	3.42
obj510	window	2.05	ventana	3.48
obj515	woman	2.65	mujer	4.34

Low Frequency Verbs

act014	bark	0.74	ladrar	1.90
act020	bow	1.31	saludar	2.74
act025	buckle	0.70	abrochar	1.26
act027	bury	1.32	enterrar	2.54
act032	carve	0.49	esculpir	1.26
act189	carve	0.49	esculpir	1.26
act037	chew	0.96	morder	2.34
act038	clap	0.67	aplaudir	1.79
act043	comb	0.78	peinar	1.49
act045	conduct	1.05	dirigir	2.76
act047	cough	0.94	toser	1.62
act221	cough	0.94	toser	1.62
act053	curl	0.37	peinarse	1.00
act056	decorate	0.36	decorar	1.99
act001	dive	1.11	clavarse	0.48
act062	drip	0.71	gotear	1.23
act066	drip	0.71	gotear	1.23
act086	drip	0.71	experimentar	2.49
act074	erase	0.79	borrar	2.58
act249	frost	0.68	decorar	1.99
act098	glue	0.77	pegar	2.52
act103	grind	0.57	guardar	3.00
act107	hatch	1.11	nacer	2.61
act111	howl	0.31	aullar	1.36

act188	itch	0.62	rascar	1.48
act120	kneel	0.73	hincar	0.78
act122	knit	0.28	tejer	1.78
act134	magnify	-0.23	observar	2.61
act141	meditate	0.01	meditar	1.88
act146	mix	1.21	batir	1.83
act150	operate	1.13	operar	2.53
act153	peel	0.73	pelar	1.78
act154	pet	1.30	acariciar	1.79
act156	pinch	0.79	pellizcar	1.15
act159	plow	0.27	arar	1.20
act183	sail	1.14	navegar	2.51
act184	salute	0.86	saludar	2.74
act195	sharpen	0.05	afilar	1.23
act196	shave	1.14	rasurar	1.20
act197	shave	1.14	rasurar	1.20
act198	shine	1.31	alumbrar	1.08
act205	skate	0.77	patinar	2.29
act214	sneeze	0.47	toser	1.62
act215	snow	1.50	nevar	1.69
act226	stack	0.79	acomodar	1.92
act230	stir	0.77	batir	1.83
act231	strain	0.85	escurrir	1.00
act254	wade	1.22	nadar	3.01
act273	yawn	0.00	bostezar	0.90
act275	zip	0.88	abrochar	1.26

High Frequency Verbs

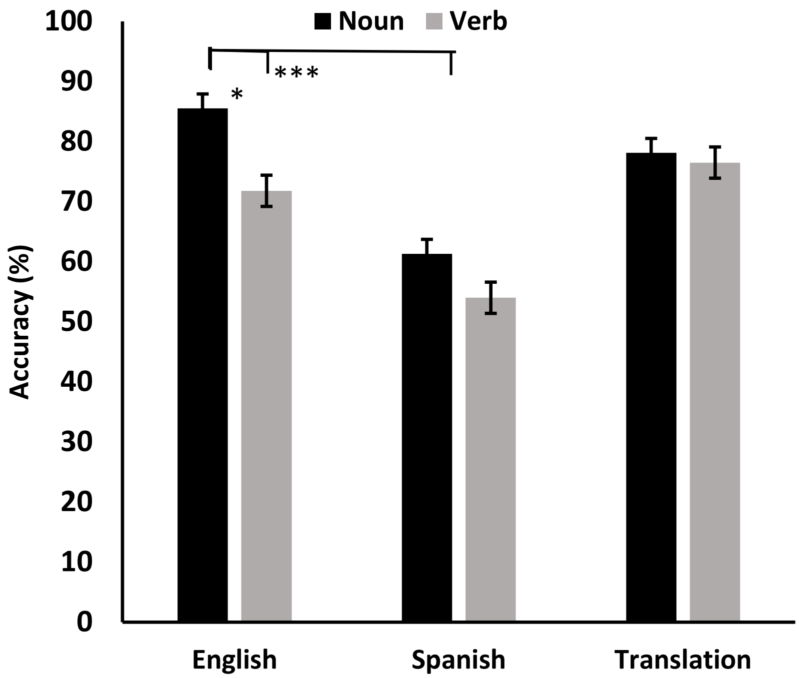
act015	beg	1.71	pedir	3.48
act048	count	1.95	contar	3.42
act174	count	1.95	contar	3.42
act051	cross	1.74	caminar	3.41
act052	cry	1.82	llorar	3.30
act095	cry	1.82	llorar	3.30
act055	dance	2.17	bailar	3.46
act002	drink	2.39	tomar	4.03
act067	drive	2.19	manejar	3.28
act072	eat	2.40	comer	3.91
act080	fall	2.07	caer	3.28
act083	fight	2.30	pelear	3.37
act084	file	1.64	buscar	3.85
act176	fix	1.94	arreglar	3.37
act009	fly	1.93	volar	3.39
act090	fly	1.93	volar	3.39

act092	follow	2.09	caminar	3.41
act123	knock	1.81	tocar	3.42
act130	listen	2.74	escuchar	3.57
act133	look	3.29	mirar	3.48
act144	mine	2.40	trabajar	3.99
act149	open	2.51	abrir	3.43
act028	pay	2.41	comprar	3.67
act044	play	2.55	tocar	3.42
act158	play	2.55	tocar	3.42
act173	read	2.38	leer	3.49
act182	run	2.54	correr	3.40
act177	save	2.21	salvar	3.51
act190	sell	1.96	vender	3.32
act207	sleep	2.36	dormir	3.86
act228	steal	1.73	robar	3.27
act244	talk	2.93	hablar	4.52
act245	think	3.43	pensar	3.99
act252	type	1.78	escribir	3.44
act256	wait	2.92	esperar	3.86
act008	walk	2.33	caminar	3.41
act257	walk	2.33	caminar	3.41
act258	wash	1.61	llorar	3.30
act259	watch	2.52	ver	4.66
act011	win	2.13	ganar	3.69
act266	win	2.13	ganar	3.69
act269	wish	2.37	pensar	3.99
act064	write	2.10	escribir	3.44
act272	write	2.10	escribir	3.44

Supplementary Table 2. Results of statistical analyses of picture naming accuracy for Experiment 2. p-values: *** < .001; ** >.01; * < .05.

	Coef β	SE (β)	t
Picture Naming Accuracy			
Fixed effects: Language x Lexical Category			
Intercept	0.54	0.03	17.8***
Lexical category (Verb)	0.07	0.04	2*
Language (Spanish)	0.18	0.04	4.9***
Lexical category x Language	0.065	0.05	0.2
Picture Naming Speed			
Fixed effects: Language x Lexical Category			
Intercept	1356.9	32.9	41.2***
Lexical category (Verb)	189.3	17.7	41.2***
Language (Spanish)	51.9	16.3	3.2**
Lexical category x Language	85.9	21.4	4***
Translation Speed			
Fixed effect: Lexical Category			
Intercept	1136	32.9	34.5***
Lexical category (Verb)	323	14.9	21.6***

For picture naming accuracy, generalized linear mixed model analysis with language (English, Spanish) and lexical category (noun, verb) as fixed effects and participants as random effects and intercept (for both fixed and random effects) and random slopes showed main effects of language and lexical category and no interaction. Participants were more accurate in English than in Spanish and also more accurate for nouns than for verbs (Supplemental Figure 1). For picture naming speed, the LME analysis with language (English, Spanish) and lexical category (noun, verb) as fixed effects and participants and items as random effects, including intercept for both fixed and random effects and random slopes was significant. There were significant effects of language, lexical category, and their interaction.



Effects of frequency and translatability on picture naming speed on Non-Cognate Stimuli in Experiment 2

Given that the stimuli included some cognates (17 nouns, 11 verbs), the effects of frequency and translatability were examined by excluding the cognates.

Translation Task: Verbs (Mean (SE) = 1136.3 (32.8)) were translated faster than nouns (Mean (SE) = 1482.1 (33.4), β (noun) = 345.8, SE = 11.1, $p < .001$),).

Picture Naming Task: A 3-way LME with lexical category (noun, verb), frequency (low, high) and translatability (low, high) as fixed effects and participants and items as random effects. The intercept was included for both fixed and random effects. For Picture naming RTs, when language and lexical category were entered as fixed effects (random slope and random intercept, and participants as random effect), there was a main effect of language (β (noun) = -177.8, SE = 19.1, $p < .001$), a main effect of lexical category (β (English) = -48.6, SE = 18.4, $p < .01$) and an interaction between language and lexical category (β (noun, English) = -99.6, SE = 25.6, $p < .001$). This finding is the same as when all stimuli were included: verbs (Mean (SE) =

1324.5 (31.4)) were slower than nouns (Mean (SE) = 1096.8 (31.3), mean difference = 227.6 ms, SE = 12.8), Spanish naming (Mean (SE) = 1259.8 (31.5)) was slower than English naming (Mean (SE) = 1161.4 (31.2) mean difference = 98.4 ms, SE = 12.9), and the Spanish-English difference was smaller for verbs (mean difference = 48.5ms) than it was for nouns (mean difference = 148.2 ms).