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Prefix priming within and across languages in early and late bilinguals

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Research Article

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Abstract

In contrast to ample evidence for cross-linguistic priming of monomorphemic words, cross-linguistic representation of affixes is not well understood. The current study examines cross-linguistic prefix priming among early and late English-Spanish bilinguals, focusing on prefixes that have the same form and meaning in the two languages. We first confirm robust prefix priming among English monolingual speakers (Experiment 1). We also observe prefix priming from first-language English to second-language Spanish but only for early bilinguals (Experiment 2). On the other hand, both early and late bilinguals do not show reliable prefix priming effects that are dissociated from orthographic or semantic priming from Spanish to English (Experiment 3) or from Spanish to Spanish (Experiment 4). The results suggest that for early bilinguals, the tested prefixes in their L1 and L2 have shared representations. Less reliable results for late bilinguals may reflect their weaker sensitivity to morphological structure in a second language.

Highlights

- Prefix priming in English and Spanish and between those languages was tested with early and late Spanish-English bilinguals.
- Robust prefix priming in one's dominant language (English) is replicated, but not in one's less dominant language (Spanish).
- Cross-language prefix priming from one's dominant language to a less dominant language was found among early bilinguals, but not late bilinguals.

1. Prefix priming within and across languages in early and late bilinguals

It is widely accepted that words in two languages that share their meaning are connected to some extent in the lexicon of bilingual language users, and more so for cognates than noncognates (Carramazza and Brones, 1979; De Groot and Nas, 1991; Dijkstra et al., 1998, 2010). However, it remains uncertain how morphologically complex words and their constituents, i.e., roots and affixes, are represented in the bilingual lexicon. In the present study, we examine cross-language affix representation throughout four experiments that test prefix priming in Spanish and English both within a first language (L1; Experiment 1), a second language (L2; Experiment 4) and between L1 and L2 (Experiment 2 and Experiment 3) using a masked priming paradigm. Based on the results, we propose an integrated representation of cognate prefixes within existing frameworks for bilingual word recognition.

2. Bilingual lexicon and morphological representation

A prominent topic in bilingualism has been the organization of the bilingual lexicon with a specific focus on how words in two languages with the same meaning are represented. Priming is a popular method to probe this matter. In this paradigm, a pair of words is presented in a sequence, and the time to recognize the latter word is measured. It has been repeatedly reported that recognition of a word is facilitated when preceded by its translation equivalent in the other language among bilinguals. This pattern is asymmetric such that L1–L2 priming is more robust than L2–L1 priming (e.g., Jiang, 1999; Smith et al., 2019; Wang, 2013; see Wen and van Heuven, 2017 for meta-analysis).

This priming pattern is captured in various models of bilingual word recognition. For example, the Revised Hierarchical Model (RHM; e.g., Kroll and Stewart, 1994; Kroll and Tokowicz, 2001, 2005) proposes that L1 and L2 words are stored in separate lexicons but are linked at the conceptual level. Asymmetric priming arises because the links between L2 words and their corresponding concepts are weaker than those between L1 words and the concepts. On the other hand, the Bilingual Interactive Activation models (BIA and BIA+; Dijkstra and Van Heuven, 2002; Van Heuven et al., 1998) assume a unified lexicon of L1 and L2 words which are represented across feature, letter, word, meaning and language levels. L2 words, due to their low frequency for unbalanced bilinguals who generally use their L1 more frequently than their L2, have lower resting levels and hence are more costly to recognize, leading to smaller L2–L1 priming effects.

These models also predict greater overlap or association for cognates as compared to noncognates, leading to differences in processing. Such differences include faster recognition of cognates than noncognates, known as the cognate facilitation effect (Carramazza and Brones, 1979; Dijkstra et al., 2010). According to the RHM, this occurs because cognates have greater form overlap and thus stronger links at the lexical level. Therefore, retrieving cognates in L2 is faster because they take advantage of their L1 counterparts. According to the BIA+, this facilitation effect arises due to shared representations of cognates at both the semantic and orthographic levels.

These models are centered around monomorphemic words, and it is less understood how morphologically complex words are represented in bilinguals. For example, are morphemic units smaller than words, i.e., roots and affixes, also connected across languages? It is widely agreed that roots and prefixes show robust priming effects within the same language at both short and long-stimulus onset asynchronies (SOAs), supporting the notion that these morphological pieces have independent representations (c.f., Amenta and Crepaldi, 2012; Cho et al., 2024). Do these same units show priming effects cross-linguistically as well? Results thus far are mixed with respect to cross-linguistic root priming. Studies by Kim and colleagues (Kim et al., 2011; Kim and Wang, 2014) show statistically reliable priming effects for Korean–English bilinguals from Korean-derived words (e.g., □력□ maylyek-cek 'attract-ive') to English words (e.g., attract) that share the same root at short SOAs (36 ms, 48 ms and 72 ms) as well as long SOA (150 ms). These results extend the literature on monomorphemic words to non-cognate morphologically complex words in two languages and demonstrate the shared representation of roots at the morphological level. On the other hand, Voga and Grainger (2007) who used cognate roots with form overlap (e.g., κανονιά "cannon-shot"-canon "cannon") failed to find cross-language root priming effects that are statistically larger than form-based priming (e.g., κανόνας "rule"-canon).

How affixes are represented in bilinguals' lexicon, specifically for those that are cognates, has not been addressed in the literature, yet prefix priming effects reported in monolingual studies as reviewed in the following section provide a useful basis to probe the representation of prefixes across L1 and L2 and within L2, which is the primary focus of the current study.

3. Monolingual prefix priming

Five studies to date have found robust prefix priming effects for monolingual speakers in French (Giraudo and Grainger, 2003), Setswana (Ciaccio et al., 2020), Spanish (Domínguez et al., 2006, 2010) and English (Chateau et al., 2002) (See Cho et al., 2024 that reports robust prefix priming across these studies in a meta-analysis). Giraudo and Grainger (2003) examined affix priming in French at three different SOAs (34 ms, 57 ms and 115 ms). Primes and targets shared either the same prefix (e.g., enjeu-envol) or suffix (e.g., fumet-muret). Across the three SOAs, prefixes yielded robust priming effects ranging from 28 ms to 40 ms, whereas suffixes did not show such priming effects. Similarly, Ciaccio et al. (2020) report statistically reliable prefix priming effects for inflection as well as derivation in Setswana, but not for suffix priming (but see Crepaldi et al., 2015 who report robust English suffix priming). Domínguez et al. (2006, 2010) report statistically reliable prefix priming effects in Spanish across different SOAs (33 ms, 132 ms and 200 ms) in both reaction times and event-related potentials, where prefix overlap between primes and targets yielded early positivity at target words (150–250 ms time window) in contrast to orthographic overlap that yielded a larger N400 effect, reflecting lexical inhibition.

Finally, in Chateau et al. (2002), prefix priming effects were tested in English in a masked priming paradigm (SOA = 45 ms). Prefixes were further categorized depending on their form-meaning consistency, high consistency if they are more frequently used as prefixes and low consistency if they are frequently used in pseudo-prefixed words (e.g., de in desert) as well. Both types of prefixes yielded faster recognition of target words that have the same prefix although the magnitude of facilitation was larger for high-consistency prefixes (36 ms) than low-consistency prefixes (24 ms). Orthographic or semantic overlap, on the other hand, did not show statistically reliable facilitation.

Based on these findings, it can be postulated that within the same language, prefixes function as independent access points from the early stage of visual word recognition, just as roots do (e.g., Rastle et al., 2000). It is this status as lexical access points that yields facilitatory priming effects even at short SOAs. Whether prefixes yield similar priming effects from one language to another has not yet been examined. We investigate this question with English-Spanish bilinguals in the current study. If prefixes show reliable cross-language priming effects, we take this as evidence for the shared representation of prefixes between languages, such that their activation in one language facilitates the subsequent access in another language.

4. L2 morphology and the effect of age of acquisition

For morphological priming to occur, individuals must be sensitive to the morphological structure of words. Previous research suggests that the degree of sensitivity to L2 morphological structure may vary among bilinguals depending on their age of L2 acquisition (AoA). For example, a series of studies report that late Turkish–German bilinguals show smaller priming effects from L2 inflected words (e.g., geprüft 'checked') to their root (e.g., prüft 'check') compared to early bilinguals (Babcock et al., 2012; Basnight-Brown and Altarriba, 2007; Veríssimo et al., 2018). In particular, Veríssimo et al. (2018) report a discontinuity of priming where priming effects were similar to monolingual speakers for bilinguals with AoA of less than 5 and decreased with higher AoA. In addition, Heyer and Clahsen (2015) examined root priming effects from derived words with bilinguals with relatively high AoA (average AoA = 9.78, SD = 2.12) and report that morphological priming did not dissociate from orthographic priming effects, indicating that late bilinguals might rely more on orthographic information than morphological structure when processing those words.

Such AoA effects in morphological processing can be considered a part of the vast literature on the 'Critical Period Hypothesis' of language learning. While this hypothesis was originally proposed for first language acquisition, it has been suggested that there may also be a *critical period* for acquiring a second language as well (e.g., Birdsong, 2009, 2018; Johnson and Newport, 1989). According to this hypothesis, language acquisition is more uniform among individuals at an earlier age (before puberty), whereas it is more variable

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after this period due to the maturation of the neural systems (Lenneberg, 1967; Long, 1990). Applying this hypothesis to second language acquisition, the Shallow Structure Hypothesis (SSH; Clahsen and Felser, 2006) claims that late L2 learners depend on fundamentally different mechanisms than early learners. Specifically, an extended version of SSH to morphological processing maintains that late L2 learners tend to rely on storing the whole word form rather than computing its internal morphological structure when processing morphologically complex words (Clahsen et al., 2010).

Given this background, the present study investigates differential prefix priming effects for early versus late bilinguals. Based on the findings in Heyer and Clahsen (2015) and Veríssimo et al. (2018), we define early bilinguals as those who learned L2 before the age of 5 and late bilinguals as those who learned L2 after the age of 10.

5. The present study

The present study examines priming effects of prefixes during visual word recognition across and within languages with AoA as a modulating factor. We use a masked priming paradigm (Forster and Davis, 1984), where a sequence of hash-marks (#####) precedes the presentation of primes to function as a forward mask and prime words are presented very briefly (50 ms in the current study). With this design, participants are unaware of the fact that they saw the prime words, which minimizes the effects of episodic or strategical factors. A total of 59 English speakers and 416 English–Spanish bilinguals participated in the experiments. Bilingual participants were divided into the early bilingual group (EB) and the late bilingual group (LB) based on their age of Spanish acquisition (AoA ≤ 5 versus AoA ≥ 10); while some of the bilinguals were simultaneous bilinguals who learned English and Spanish around the same time, they were more dominant in English. Hence, for the sake of simplicity, we label English (dominant language) as their L1 and Spanish (less dominant language) as L2. A total of four experiments were conducted: Experiment 1 investigated the masked priming effects of prefixes in participants' L1 (English). Experiments 2 and 3 investigated masked prefix priming across different languages, from L1 to L2 (Experiment 2) and from L2 to L1 (Experiment 3), using cognate prefixes that have the same form and meaning in the two languages (e.g., *pre* in English word *pretext* and Spanish word *predecir*). Lastly, Experiment 4 tested masked prefix priming in participants' L2.

6. Experiment 1. L1–L1 priming

In Experiment 1, we tested prefix priming with English speakers. Both primes and targets were presented in English with the stimulus onset asynchrony (SOA) of 50 ms.

7. Methods

7.1. Participants

Fifty nine English speakers (26 males, 30 females, 3 other responses; age: mean = 34.9, SD = 12.91) were recruited via the online recruitment platform Prolific. One participant who reported to have learned English at age 16 was excluded from data analysis. The remaining 58 participants were residing in the United Kingdom (*N* = 38) or the United States (*N* = 20) at the time of participating in the study. They all reported English to be their first language and dominant language as indicated by their daily use of English, which was 96.5% (SD = 13.97) on average. Most participants (*N* = 42) did not speak other languages than English; 16 participants reported some knowledge of Polish (*N* = 2), French (*N* = 5), German (*N* = 2), Portuguese (*N* = 1), Spanish (*N* = 4), or Punjabi (*N* = 2).

7.2. Stimuli

Stimuli consisted of 240 prime-target pairs with target words and 120 prime-target pairs with target pseudowords. All prime and target words were English words. Prime words paired with word targets were either Related or Unrelated to target words in one of four dimensions; Related primes were identical to target words ("Identical," e.g., hang-HANG) or shared the same prefix ("Prefix," e.g., distract-DISSUADE), word-initial letters ("Orthography," ignite-IGNORE), or meaning ("Semantic," e.g., elect-VOTE). Unrelated primes did not have any orthographic or semantic overlap with target words and were bimorphemic prefixed words (e.g., unbend) for the Prefix condition and monomorphemic for Identity, Orthography and Semantic conditions. Word targets were verbs, adjectives, or nouns consisting of bimorphemic prefixed words for Prefix conditions and monomorphemic for the other three conditions. Each prime type was formed into 60 word-pairs with 30 Related primes and 30 Unrelated primes. All primes were presented in lowercase letters and targets in uppercase letters. See Appendix A for the full stimulus set.

The lexical characteristics of the target words and prime words across conditions are summarized in Table 1. Log word frequency per million obtained from CLEARPOND (Marian et al., 2012) was used as a measure of word frequency. This resource was used because it provides word frequency measures for Spanish as well as English so that it allows a more even comparison between the two languages in subsequent cross-language priming experiments. Here we also report log word frequency per million obtained from British National Corpus (BNC; Davies, 2004) as well as log HAL frequency measures obtained from the English Lexicon Project (Balota et al., 2007) for reference. The frequency measures obtained from CLEARPOND and BNC show a relatively high correlation (r = 0.67). Semantic similarity between prime words and target words was calculated as the cosine distance between word vectors using the pre-trained GloVe word embeddings (Pennington, 2014). All unrelated primes had a cosine distance <0.37; this threshold follows previous studies (Grainger and Frenck-Mestre, 1998; Rastle et al., 2000). Finally, the orthographic overlap between prime and target words was quantified with length-normalized Levenshtein distance (Schepens et al., 2012), with the value ranging from 0 to 1 (1 = perfect overlap). Related primes in Prefix and Orthography conditions had initial letters overlapping with target words (2–5 letters in Prefix condition, 2–3 letters in Orthography condition), resulting in the average Levenshtein distance of approximately 0.45. The number of overlapping letters between target words and prime words in other conditions was kept minimum, hence the average Levenshtein distance was 0.10 or below.

In addition to target words, 120 target pseudowords were constructed, 30 of which resembled prefixed words, such that half of them were generated by combining existing prefixes and pseudowords and the other half were generated by combining non-existing prefixes and real words. Other pseudoword targets were generated with the Wuggy tool (Keuleers and Brysbaert, 2010). Prime-target pairs with word targets were separated into two different lists; those with pseudoword targets were the same across lists. Consequently,

Table 1. Lexical characteristics of target and prime words used in Experiment 1 (SD in parentheses)

Condition	Word length	Log frequency CLEARPOND	Log frequency BNC	Log frequency HAL	Semantic relatedness	Levenshtein distance*
Identity target	4.53 (1.43)	1.87 (0.47)	0.71 (0.51)	10.12 (1.23)	-	-
Related prime	4.53 (1.43)	1.87 (0.47)	0.72 (0.52)	10.12 (1.23)	1.00 (0.00)	1.00 (0.00)
Unrelated prime	5.07 (0.94)	1.67 (0.52)	0.56 (0.63)	9.75 (1.32)	0.24 (0.09)	0.07 (0.09)
Prefix target	8.70 (1.78)	0.46 (0.70)	−0.47 (1.03)	7.74 (1.80)	-	-
Related prime	8.30 (1.73)	0.53 (0.50)	−0.68 (0.91	7.41 (1.67)	0.26 (0.15)	0.46 (0.11)
Unrelated prime	8.20 (1.67)	0.21 (0.46)	−0.35 (0.67)	6.24 (2.09)	0.11 (0.12)	0.10 (0.09)
Orthography target	5.97 (1.00)	1.21 (0.71)	0.28 (0.97)	9.40 (2.06)	-	-
Related prime	6.33 (1.21)	0.66 (0.75)	0.35 (0.70)	7.81 (1.78)	0.18 (0.11)	0.45 (0.13)
Unrelated prime	5.40 (1.04)	1.30 (0.68)	0.60 (0.48)	9.35 (1.74)	0.19 (0.09)	0.07 (0.08)
Semantic target	4.43 (1.33)	1.85 (0.70)	0.79 (0.61)	9.92 (2.39)	-	-
Related prime	4.83 (1.18)	1.57 (0.62)	0.60 (0.63)	9.75 (1.34)	0.61 (0.10)	0.09 (0.13)
Unrelated prime	4.97 (0.90)	1.52 (0.64)	−1.10 (1.06)	9.58 (1.62)	0.24 (0.09)	0.08 (0.11)

*Normalized to length.

each participant saw 120 word pairs with word targets (15 items per condition) and 120 pairs with pseudoword targets.

7.3. Procedure

Participants first completed a language background questionnaire. Then they were assigned one of the two lists for the experiment. They used their own computer to perform the experiment implemented in an online platform (https://pavlovia.org) with PsychoPy (version 2020.1.3). They completed a practice session of 15 trials prior to the main session. In each trial, a forward mask (#######) was presented in the center of the monitor for 30 frames (approximately 480 ms at 60 Hz[1]), followed by a prime word presented for three frames (approximately 50 ms). Then a target word was presented for which participants performed a lexical decision task by pressing keyboards to the question "is this a real word or not" as fast as they can ('z' for 'yes' and 'm' for 'no'). Items were randomly presented in a single block.

A frame-by-frame analysis of pilot data collected over this platform confirmed stimulus timing accuracy. Specifically, we recorded the pilot experiment on an uncontrolled laptop with a 60 Hz frame rate and analyzed the stimulus presentation duration, which revealed that 199 of 200 trials were at 80.5% (or within 8.3 ms) of the intended duration. See also Angele et al. (2022) and Cayado et al. (2023) who demonstrate the feasibility of testing masked priming in online platforms including Prolific and Gorilla.

7.4. Data analysis

Prior to the experiment, the accuracy cut-off was set to 70% for participants and 50% for items. No participant or item was removed based on this criterion. Also, reaction times that are too fast (less than 200 ms) or slow (greater than 2000 ms) were excluded from data analysis, which resulted in removing 2.5% of all data points. For statistical analysis, accuracies were analyzed with a generalized mixed effects regression model using the *glmer* function in R. This model had Condition (Identity, Prefix, Orthography and Semantic) and Relatedness (Related versus Unrelated) and their interaction as fixed effects and centered Target word frequency and Prime word frequency as fixed covariates.

As reaction times are positively skewed, they were inverse-transformed based on the lambda value (−1.19) examined by the box cox test (Box and Cox, 1964) using the boxcox() function in the MASS package (Venables and Ripley, 2002). The transformed RTs were analyzed with a linear mixed effects regression analysis with the *lmer* function in the lme4 package (Bates et al., 2015). Fixed effects included Relatedness (Related versus Unrelated) and Condition (Identity, Prefix, Orthography and Semantic) and their interaction. In addition, Target word frequency, Prime word frequency, Target word length, and Prime word length were included as covariates. All continuous variables were centered and dummy coding was used for Condition with Prefix as the reference for both analyses, such that the intercept is the mean of Prefix condition and each contrast compares Prefix and Identity (Condition 1), Prefix and Orthography (Condition 2), and Prefix and Semantic conditions (Condition 3). Results from the most complex model that reached convergence are reported, which included random intercepts for items and participants for both accuracies and RTs. The model simplification process was completed by removing one random slope at a time until the model converged. Confidence intervals and *p*-values were computed using the Kenward–Roger approach (Kenward and Roger, 1997) by setting the df_method to "Kenward" in the model_parameters() function in *parameters* package (Lüdecke et al., 2020). All post-hoc analyses were conducted using emmeans() function in *emmeans* package (Lenth, 2023). Effects were considered statistically reliable for *p*-values less than 0.05.

8. Results

Table 2 shows by-subject accuracy rates and mean reaction times (RTs) for word targets. Mean RTs for each condition with standard errors are plotted in Figure 1A.

[1]All participants had a monitor refresh rate of 60 Hz as recorded by PsychoPy (version 2020.1.3).

Table 2. By subject accuracy rates and mean RTs for word targets in Experiment 1 (SD in parentheses)

Condition	Accuracy rate (%)	RT (ms)	Priming effect (ms)
Identity			
Related	98.5 (3.81)	651 (93.26)	32*
Unrelated	99.2 (2.20)	683 (94.66)	
Prefix			
Related	93.1 (7.53)	816 (149.78)	29*†
Unrelated	94.0 (5.73)	845 (157.36)	
Orthography			
Related	96.5 (5.09)	729 (97.23)	−7
Unrelated	95.7 (5.24)	722 (112.26)	
Semantic			
Related	97.8 (4.56)	683 (100.2)	5
Unrelated	98.7 (3.18)	688 (92.35)	

*$p < 0.05$ in pairwise comparisons of RT.
†Prefix priming that is statistically different from orthographic priming ($p < 0.05$).

Accuracy rates were generally high in all conditions, and no significant difference was found between Related versus Unrelated primes in Prefix condition (*Odds ratio* = 1.124, 95% CI = [0.664, 1.903], p = 0.664), nor did it interact with other conditions ($ps > 0.156$).

The linear mixed effects regression model with reaction times as a dependent variable showed statistically reliable Prefix priming (Relatedness; $\beta = 0.040$, 95% CI = [0.013, 0.068], $p = 0.003$). Its size was smaller than that of Identity priming (Relatedness × Condition1; $\beta = 0.040$, 95% CI = [0.003, 0.078], $p = 0.034$) but larger than that of Orthography (Relatedness × Condition2; $\beta = -0.054$, 95% CI = [−0.094, −0.014], $p = 0.008$). The size was not statistically different from Semantic priming (Relatedness × Condition3; $\beta = -0.026$, 95% CI = [−0.063, 0.012], $p = 0.178$). In addition, the main effects of Target word frequency ($\beta = 0.068$, 95% CI = [0.042, 0.094], $p < 0.001$), Prime word frequency ($\beta = 0.018$, 95% CI = [0.004, 0.033], $p = 0.011$), and Target word length ($\beta = -0.022$, 95% CI = [−0.034, −0.010] $p < 0.001$) were statistically reliable, such that reaction times were faster for shorter and more frequent target words and also when target words were preceded by more frequent prime words. (See Supplementary Materials for full summary of the model).

Post-hoc pairwise comparisons were conducted to probe priming effects for each of Identity, Orthography and Semantic conditions. Identity priming effects ($\beta = 0.071$, 95% CI = [0.043, 098], $p < 0.001$) were statistically reliable, but not Orthographic priming effects ($\beta = -0.007$, 95% CI = [−0.041, 0.028], $p = 0.711$) or Semantic priming effects ($\beta = 0.014$, 95% CI = [−0.012, 0.039], $p = 0.290$).

9. Discussion

Experiment 1 tested masked prefix priming effects in English with English dominant speakers in comparison to identity, orthography, and semantic priming effects. The results show that only Identity and Prefix conditions show reliable masked priming effects

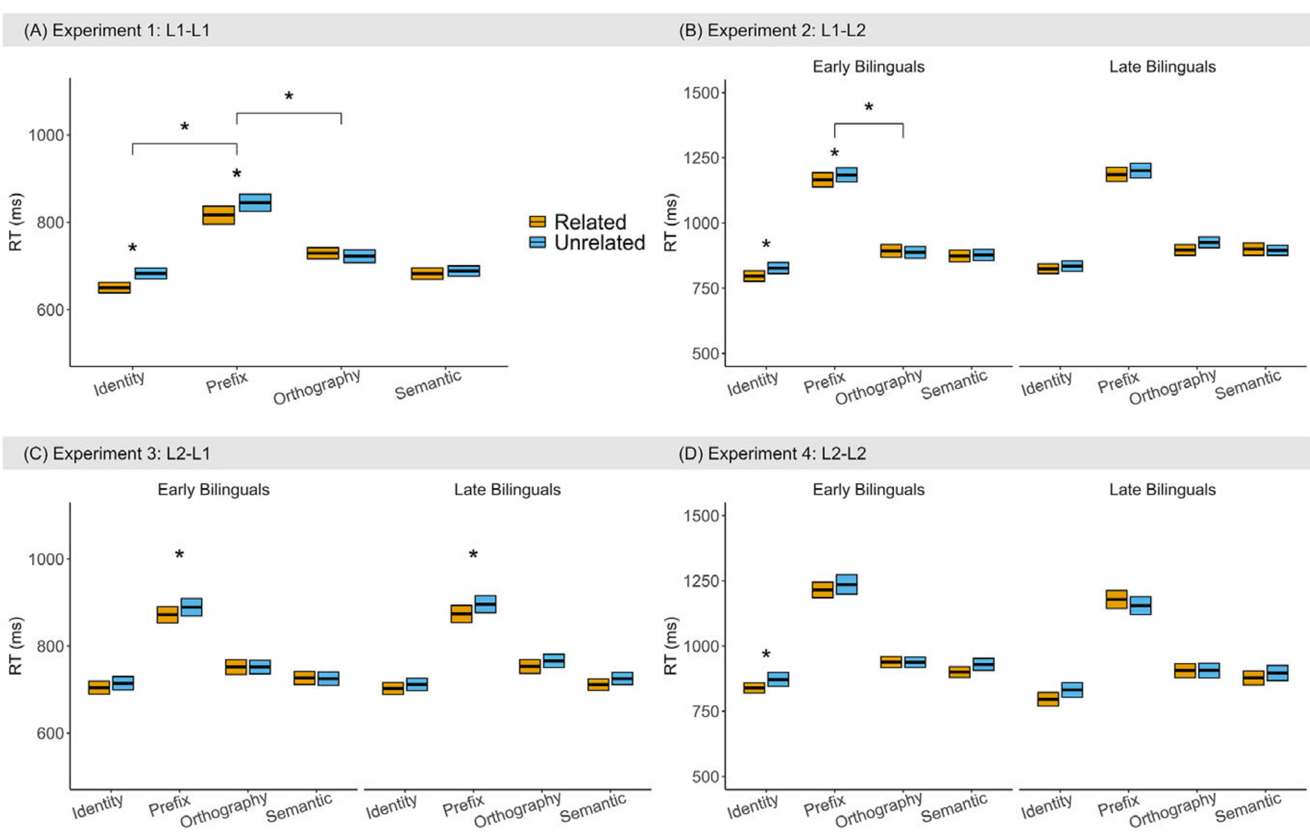

Figure 1. Mean RTs and standard errors for target words in Experiments 1–4.
Note. Asterisks indicate $p < 0.05$.

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(Identity: 32 ms; Prefix: 29 ms). These results replicate previous studies on prefix priming in monolingual settings (Chateau et al., 2002; Domínguez et al., 2006, 2010; Giraudo and Grainger, 2003) and confirm that prefixes in morphologically complex words are identified and facilitate the subsequent access within the same language.

Importantly, the null priming effects in Orthography and Semantic conditions suggest that the prefix priming effects are not a result of form or semantic overlap but rather of morphological overlap. The statistical distinction between prefix priming and orthographic priming is a replication of Domínguez et al. (2006, 2010), confirming that these two effects are statistically separable with our methods. A comparison between prefix priming and semantic priming has not been reported in previous studies, and the interaction in the current study did not reach statistical significance. Yet, we tentatively suggest that semantic overlap may have a minimal contribution, if any, to prefix priming, given that its priming effects are numerically small (5 ms compared to 29 ms for prefix priming) and statistically unreliable.

In short, the results from Experiment 1 demonstrate robust masked priming effects of prefixes in one's dominant language. In the following three experiments (Experiment 2–4), we examine prefix priming effects between L1 and L2 and within L2.

10. Experiments 2–4

Experiments 2–4 tested prefix priming in the directions of L1–L2 (Experiment 2), L2–L1 (Experiment 3), and L2–L2 (Experiment 4) by early and late English-Spanish bilinguals to examine whether cognate prefixes in different languages prime each other as well as within one's second language.

11. Methods

11.1. Participants

A total of 414 English–Spanish bilinguals were recruited via Prolific. All of them were living in the United Kingdom ($N = 152$) or in the United States ($N = 262$) at the time of participating in the study. Among them, 135 participants (77 females, 57 males, 1 other response) participated in Experiment 2 (L1–L2), 137 participants (74 females, 61 males, 2 other response) in Experiment 3 (L2–L1) and 142 participants (71 females, 70 males, 1 other response) in Experiment 4 (L2–L2). They were then further grouped into early bilinguals (EB) or late bilinguals (LB) based on their age of acquisition. The former group learned English and Spanish during early childhood (at or before age of 5), while the latter group learned English as their native language and Spanish a second language at or after age of 10 (Heyer and Clahsen, 2015; Veríssimo et al., 2018). Table 3 shows the details of the language background of the groups in each experiment.

Table 3. Language background of participants in Experiments 2–4

	Early bilinguals	Late bilinguals
Experiment 2 (L1–L2)		
Number of participants	69	68
Age	31.1 (10.17)	34.3 (13.79)
Age of Spanish acquisition	2.0 (1.74)	15.2 (5.89)
English daily use (%)	83.0 (15.51)	87.8 (19.39)
Spanish daily use (%)	24.6 (20.49)	12.23 (15.94)
Self-rated English proficiency (1–7)	6.8 (0.58)	6.9 (0.24)
Self-rated Spanish proficiency (1–7)	5.9 (0.82)	5.1 (0.82)
Experiment 3 (L2–L1)		
Number of participants	70	67
Age	33.3 (12.23)	36.7 (13.56)
Age of Spanish acquisition	2.1 (1.98)	14.3 (5.39)
English daily use (%)	84.2 (13.02)	91.6 (12.63)
Spanish daily use (%)	19.8 (17.36)	8.95 (11.34)
Self-rated English proficiency (1–7)	6.9 (0.32)	7.0 (0.13)
Self-rated Spanish proficiency (1–7)	5.6 (0.86)	5.1 (0.81)
Experiment 4 (L1–L2)		
Number of participants	73	69
Age	30.3 (8.94)	37.4 (13.74)
Age of Spanish acquisition	2.1 (1.95)	15.7 (8.07)
English daily use (%)	78.4 (19.80)	87.8 (20.14)
Spanish daily use (%)	26.8 (23.14)	13.1 (14.49)
Self-rated English proficiency (1–7)	6.9 (0.40)	6.8 (0.68)
Self-rated Spanish proficiency (1–7)	6.3 (0.79)	5.2 (1.14)

11.2. Stimuli

Each experiment stimuli consisted of 240 prime words and 120 target words that were either English or Spanish according to the corresponding language pair of the experiment. The majority of English prime and target words were the same as in Experiment 1 with some adjustments. The prime-target word pairs were non-cognate translation equivalents of each other ("Identity"), or shared the same prefix ("Prefix"), word-initial letters ("Orthography"), or meaning ("Semantic"). Each pair was matched with Unrelated prime-target pairs with no orthographic or semantic relation that were bimorphemic for Prefix condition and monomorphemic for all other conditions. The lexical characteristics of prime words were measured in the same manner as described for Experiment 1. For prime-target pairs that contained Spanish words, semantic similarity was measured based on English translation equivalents of the Spanish words. See Table 4 for example stimuli and a summary of lexical characteristics of target words and prime words for each experiment.

In addition, 120 Spanish pseudowords were constructed in the same way as English pseudowords used in Experiment 1. Participants in Experiment 2 (L1–L2) and Experiment 4 (L2–L2) saw 120 Spanish pseudowords along with 120 Spanish word targets (15 items per condition) following English or Spanish primes, respectively, whereas those in Experiment 3 (L2–L1) saw 120 English pseudowords and 120 English word targets (15 items per condition) after Spanish primes.

11.3. Procedure

The procedure was the same as in Experiment 1. At the end of each experiment, participants additionally completed Lextale-Esp (Izura et al., 2014) implemented in Psychopy as a measure of their Spanish

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Table 4. Lexical characteristics of target and prime words used in Experiments 2–4 (SD in parentheses)

Condition	Example target and prime	Word length	Log frequency	Semantic relatedness	Levenshtein distance*
Experiment 2 (L1–L2)					
Identity target	COLGAR [hang]	5.48 (1.23)	1.76 (0.54)	-	-
Related prime	hang	4.53 (1.43)	1.90 (0.48)	1.00 (0.00)	0.17 (0.15)
Unrelated prime	erase	4.93 (0.78)	1.60 (0.52)	0.23 (0.09)	0.02 (0.05)
Prefix target	DISGUSTAR [upset]	9.26 (1.61)	1.10 (0.53)	-	-
Related prime	distract	8.37 (1.79)	0.50 (0.63)	0.22 (0.15)	0.45 (0.10)
Unrelated prime	unbend	8.27 (1.93)	0.23 (0.50)	0.08 (0.09)	0.09 (0.07)
Orthography target	IGUALAR [equalize]	6.47 (1.29)	1.38 (0.62)	-	-
Related prime	ignite	6.23 (1.13)	0.60 (0.79)	0.17 (0.15)	0.42 (0.09)
Unrelated prime	smile	5.57 (1.19)	0.74 (0.09)	0.24 (0.13)	0.10 (0.12)
Semantic target	VOTAR [vote]	6.23 (1.69)	1.61 (0.69)	-	-
Related prime	elect	4.87 (1.10)	1.44 (0.80)	0.58 (0.16)	0.07 (0.09)
Unrelated prime	Spend	4.90 (0.80)	1.44 (0.65)	0.23 (0.08)	0.06 (0.10)
Experiment 3 (L2–L1)					
Identity target	HANG	4.53 (1.43)	1.87 (0.47)	-	-
Related prime	colgar [hang]	5.46 (1.28)	1.72 (0.47)	1.00 (0.00)	0.16 (0.15)
Unrelated prime	borrar [erase]	5.80 (1.27)	1.65 (0.55)	0.24 (0.09)	0.06 (0.08)
Prefix target	DISTRACT	8.37 (1.79)	1.04 (0.63)	-	-
Related prime	disgustar [upset]	9.20 (1.54)	0.40 (0.32)	0.18 (0.13)	0.45 (0.09)
Unrelated prime	subrayar [underline]	8.50 (1.66)	0.69 (1.44)	0.12 (0.11)	0.07 (0.09)
Orthography target	IGNORE	5.93 (1.00)	1.33 (0.70)	-	-
Related prime	igualar [iqualize]	6.73 (1.36)	1.37 (0.68)	0.23 (0.13)	0.40 (0.14)
Unrelated prime	volver [return]	6.17 (1.44)	1.69 (0.69)	0.20 (0.14)	0.05 (0.08)
Semantic target	ELECT	4.83 (1.18)	1.57 (0.62)	-	-
Related prime	votar [vote]	6.13 (1.72)	1.64 (0.70)	0.55 (0.16)	0.08 (0.09)
Unrelated prime	gastar [spend]	6.03 (1.38)	1.33 (0.65)	0.25 (0.11)	0.08 (0.08)
Experiment 4 (L2–L2)					
Identity target	COLGAR [hang]	5.48 (1.23)	1.76 (0.54)	-	-
Related prime	colgar [hang]	5.50 (1.25)	1.75 (0.55)	1.00 (0.00)	1.00 (0.00)
Unrelated prime	borrar [erase]	6.10 (1.54)	1.41 (0.62)	0.27 (0.11)	0.05 (0.14)
Prefix target	DISGUSTAR [upset]	9.32 (1.65)	1.07 (0.54)	-	-
Related prime	distractir [distract]	9.27 (1.86)	0.64 (0.59)	0.31 (0.13)	0.49 (0.14)
Unrelated prime	subrayar [underline]	8.57 (1.70)	0.95 (0.66)	0.23 (0.09)	0.09 (0.07)
Orthography target	IGUALAR [equalize]	6.57 (1.28)	1.34 (0.62)	-	-
Related prime	ignorar [ignore]	6.73 (1.26)	1.14 (0.73)	0.30 (0.12)	0.43 (0.09)
Unrelated prime	volver [return]	6.70 (1.39)	1.09 (0.77)	0.28 (0.09)	0.10 (0.12)
Semantic target	ELEGIR [choose]	6.23 (1.72)	1.62 (0.70)	-	-
Related prime	votar [vote]	5.93 (1.74)	1.39 (0.71)	0.52 (0.14)	0.07 (0.09)
Unrelated prime	gastar [spend]	6.73 (1.53)	1.42 (0.77)	0.29 (0.10)	0.06 (0.10)

*Normalized to length.

proficiency[2]. This test consists of 60 Spanish words and 30 pseudowords presented one at a time. Participants were asked to decide whether each string of letters is a Spanish word or not.

11.4. Data analysis

For each experiment, participants with accuracy rates less than 70% and items with accuracy rates less than 50% were removed from data analysis as well as reaction times less than 200 ms and greater than 2000 ms.[3]

Accuracies were analyzed with a generalized mixed-effects regression model with binomial family. Fixed effects included Relatedness (Related versus Unrelated), Condition (Identity, Prefix, Orthography, and Semantic), and Group (EB versus LB) and their interactions, and centered Target word frequency and Prime word frequency as fixed covariates.

Reaction times were transformed according to the lambda value from the box cox test (Box and Cox, 1964) using the boxcox() function to account for positive skewness. This resulted in inverse-transformation in Experiments 2 and 3 and log transformation in Experiment 4. The transformed RTs were analyzed with a linear mixed-effects regression model with Condition, Relatedness, and Group and their interactions as fixed effects. In addition, Target word frequency, Prime word frequency, Target word length, and Prime word length were centered and included as fixed covariates. For both analyses, the Condition variable was dummy coded with Prefix as the reference level; therefore, each contrast compares Prefix and Identity (Condition 1), Prefix and Orthography (Condition 2) and Prefix and Semantic conditions (Condition 3). Results from the most complex model that reached convergence are reported, which included random slope for Relatedness for item and random intercepts for items and participants for accuracies, and random slopes and intercepts for both accuracies and reaction times. As in Experiment 1, confidence intervals and *p*-values were derived from the Kenward–Roger approach (Kenward and Roger, 1997) using the model_parameters() function in parameters package (Lüdecke et al., 2020). The alpha was set to 0.05.

12. Experiment 2 (L1–L2 priming) results and discussion

Experiment 2 was conducted to investigate cross-linguistic masked priming effects of prefixes from one's dominant language (L1, English) to non-dominant language (L2, Spanish).

12.1. Results

Three participants and five items were excluded from data analysis due to low accuracy rates (<70% and <50%, respectively). Following this, reaction times less than 200 ms or greater than 2000 ms were excluded, which accounted for 10.0% of the data.

Participants' Lextale-Esp scores were computed as percentage of correctly answered word trials minus incorrectly answered pseudoword trials. The mean score for the EB group was 58.6 (SD = 12.19) and for the LB group 57.5 (SD = 13.70) with no significant difference between groups (t (134.21) = 0.51, $p = 0.612$). All participants fell under the B2 level (upper intermediate) or lower based on their scores (Lemhöfer & Broersma, 2012).

Table 5 shows accuracies and reaction times by the two groups (Also see Figure 1B for reaction times). In the statistical analysis, accuracies were significantly lower in the Prefix condition compared to other three conditions (all $p < 0.001$), and for less frequent target words (*Odds ratio* = 2.810, 95% CI = [1.833, 4.308], $p = 0.001$). Importantly, the effect of Relatedness in the reference (Prefix) condition was statistically significant (*Odds ratio* = 1.307, 95% CI = [1.040, 1.643], $p = 0.022$), indicating that accuracy rates were higher when primes and targets shared the same prefix; post-hoc analysis showed that this effect was statistically significant only for the EB group (*Odds ratio* = 1.441, 95% CI = [1.032, 2.011], $p = 0.032$) and not the LB group (*Odds ratio* = 1.156, 95% CI = [0.829, 1.613], $p = 0.393$) although the interaction between Relatedness and Group did not reach statistical significance (*Odds ratio* = 0.849, 95% CI = [0.542, 1.330], $p = 0.476$).

The linear mixed effects regression model showed that prefix priming effects on reaction times did not reach statistical significance (Relatedness; $\beta = 0.023$, 95% CI = [−0.001, 0.047], $p = 0.060$). This effect showed a three-way interaction with Condition 2 (Prefix versus Orthography) and Group ($\beta = 0.063$, 95% CI = [0.005, 0.123], $p = 0.035$). The main effects of Target word frequency ($\beta = 0.076$, 95% CI = [0.046, 0.106], $p < 0.001$) and Target word length ($\beta = -0.044$, 95% CI = [−0.056, −0.031], $p < 0.001$) were also statistically significant, indicating faster reaction times for more frequent and shorter target words. Post-hoc analyses were conducted separately for each group to further investigate the three-way interaction. For the EB group, both Identity priming effects ($\beta = 0.042$, 95% CI = [0.019, 0.065] $p < 0.001$) and Prefix priming effects ($\beta = 0.037$, 95% CI = [0.006, 0.069], $p = 0.019$) were statistically reliable as well as the difference between Prefix and Orthographic priming effects ($\beta = -0.058$, 95% CI = [−0.100, −0.016], $p = 0.007$). Priming effects of Orthography and Semantic conditions were not statistically reliable (all $p > 0.122$). For the LB group, none of the priming effects reached statistical significance (all $p > 0.129$), neither was the difference between Prefix priming effects and Orthographic priming effects statistically reliable ($\beta = 0.013$, 95% CI = [−0.035, 0.060], $p = 0.600$).

In summary, only the EB group shows statistically reliable Identity priming effects and Prefix priming effects. In addition, a dissociation of Prefix priming effects and Orthographic priming effects is observed only for the EB group.

12.2. Discussion

Experiment 2 was conducted to test whether prefixes prime from a first to a second language. To this end, 135 English-Spanish bilinguals were recruited, who are further split into two groups based on their age of acquisition of Spanish – early bilinguals ($N = 69$) and late bilinguals ($N = 68$). The results show statistically reliable priming effects for prefixes as well as translation equivalents only for the EB group who acquired their second language before the age of 5. Also, the three-way interaction of Group, Relatedness and Condition 2 (Prefix versus Orthography) indicates that the prefix

[2]Although this test measures explicit vocabulary knowledge, previous studies show that Lextale scores correlate well with implicit vocabulary measures such as priming effects (e.g., Ferré and Brysbaert, 2017; Hopp and Grüter, 2023; Meade et al., 2022).

[3]As reaction times in one's L2 tend to be longer than L1, additional analyses were conducted for Experiment 2 and Experiment 4 with an upper cut-off for RT exclusions of 3,000 ms following Foote et al. (2020) and Yamashita and Jiang (2010). This resulted in removing 4.5% of data points in Experiment 2 and 8.5% in Experiment 4. The results showed similar patterns as the original analysis for both experiments. Also, analyses without any participant or item exclusion showed similar results as the original analysis. Analysis code for these auxiliary analyses are available in the OSF repository.

Table 5. By subject accuracy rates and mean RTs for word targets in Experiments 2–4 (SD in parentheses)

	EB			LB		
Condition	Accuracy rate (%)	RT (ms)	Priming effect (ms)	Accuracy rate (%)	RT (ms)	Priming effect (ms)
Experiment 2 (L1–L2)						
Identity						
Related	97.2 (8.76)	797 (168.64)	30*	96.7 (6.59)	824 (146.00)	10
Unrelated	98.2 (4.56)	827 (175.88)		96.3 (6.13)	834 (156.19)	
Prefix						
Related	81.2 (18.09)	1165 (223.23)	19*†	75.6 (21.36)	1186 (211.11)	14
Unrelated	79.1 (21.27)	1184 (221.46)		72.1 (24.31)	1200 (221.81)	
Orthography						
Related	93.7 (9.90)	893 (203.07)	−7	91.2 (9.55)	896 (165.37)	29
Unrelated	94.9 (6.93)	886 (185.05)		89.8 (11.70)	925 (168.64)	
Semantic						
Related	97.5 (4.47)	873 (186.05)	4	92.5 (8.85)	900 (190.22)	−5
Unrelated	96.8 (5.59)	877 (175.68)		94.8 (7.84)	895 (155.60)	
Experiment 3 (L2–L1)						
Identity						
Related	96.7 (5.67)	704 (125.81)	11	99.5 (1.82)	702 (113.09)	10
Unrelated	97.0 (6.57)	715 (128.71)		99.2 (2.32)	712 (118.18)	
Prefix						
Related	88.7 (15.42)	871 (156.87)	18*	93.4 (9.18)	874 (161.53)	22*
Unrelated	87.0 (14.00)	889 (169.05)		91.5 (9.14)	896 (160.00)	
Orthography						
Related	92.6 (10.51)	752 (142.65)	−1	95.5 (7.06)	753 (130.46)	13
Unrelated	92.5 (9.26)	751 (132.07)		95.6 (5.56)	766 (125.35)	
Semantic						
Related	97.0 (5.15)	726 (125.61)	−1	98.1 (4.11)	711 (107.96)	14
Unrelated	97.0 (5.44)	725 (126.43)		98.5 (2.89)	725 (114.20)	
Experiment 4 (L2–L2)						
Identity						
Related	95.6 (9.88)	835 (154.87)	34*	96.5 (9.53)	804 (205.46)	38
Unrelated	96.1 (8.45)	869 (206.92)		95.5 (11.34)	842 (231.13)	
Prefix						
Related	76.0 (20.58)	1199 (246.65)	21	77.2 (22.88)	1188 (263.43)	−32
Unrelated	72.1 (23.54)	1220 (294.49)		76.2 (21.21)	1156 (251.90)	
Orthography						
Related	89.4 (13.97)	932 (169.72)	−1	88.9 (13.89)	909 (202.43)	10
Unrelated	91.8 (10.07)	931 (160.72)		89.8 (16.43)	919 (230.20)	
Semantic						
Related	92.0 (17.83)	897 (160.13)	17	94.6 (14.36)	878 (202.76)	33
Unrelated	95.2 (8.64)	914 (191.19)		95.3 (9.80)	911 (245.75)	

*$p < 0.05$ in pairwise comparisons of RT.
†Prefix priming that is statistically different from orthographic priming ($p < 0.05$).

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priming effects are dissociable from orthographic priming effects for the EB group, unlike the LB group.

These results suggest that at least for early bilinguals, cognate prefixes in two languages form connected representations. Models on the representation of bilingual lexicon differ in how exactly these connections might be instantiated. For RHM, it could be that cognate prefixes are also stored in separate lexicons, as word representations are, and share conceptual links as well as lexical links to each other. When a morphologically complex word that contains a cognate prefix is presented in one language, the word is decomposed into its root and prefix, which then activates the prefix in the other language via conceptual links and lexical links, thus leading to facilitative cross-language prefix priming effects.

An alternative explanation is shared representation without morphological decomposition. This position is based on distributed approaches which includes the BIA and BIA+ models. In these models, morphology does not form discrete representations in the mental lexicon (Jared et al., 2017; Plaut and Gonnerman, 2000; Stevens and Plaut, 2022). Rather, morphology is an emergent property due to consistent form-meaning mappings. According to these approaches, morphological priming occurs when the consistent form-meaning mappings facilitate recognizing a word. If words in two languages are integrated at multiple levels as assumed in BIA and BIA+ models, it follows that cognate prefixes in two languages may share the same nodes at both orthographic and semantic levels such that activating a prefix in one language speeds up recognizing a word that has the same prefix in the other language. The current study does not aim to directly tease apart these two approaches to the bilingual lexicon. Still, a remaining question is whether cognate prefixes also show asymmetric priming, that is, whether priming effects are smaller, if any, in the L2–L1 direction. This is tested in Experiment 3.

A separate contribution concerns the absence of prefix priming for late bilinguals; this suggests that the representation of cognate prefixes may vary depending on the age of L2 acquisition. The lack of robust priming effects for late bilinguals may be due to either a weaker connection between L1 prefix and L2 prefix or their less sensitivity to L2 morphological structure. We examine these different possibilities further in Experiment 3 and Experiment 4.

Finally, we also observe different patterns between the two groups in translation priming. While such AoA effects on L1–L2 translation priming are not predicted from bilingual lexicon models reviewed thus far, several studies have reported AoA effects on bilingual word recognition, such as in L2–L1 translation priming (Sabourin et al., 2014) and within-L2 categorical priming (Kotz, 2001; Kotz and Elston-Güttler, 2004). Also note that the stimuli used for translation priming in the present study were non-cognate pairs, whose priming effects are known to be less consistent than cognates (e.g., Kirsner et al., 1980; Davis et al., 2010) as they are only conceptually mediated in contrast to cognates that are either lexically mediated (Kroll and Stewart, 1994; Kroll and Tokowicz, 2001, 2005) or share connections at the orthographic level (Van Heuven et al., 1998). Hence, one possible factor for the absence of translation priming from late bilinguals is that late exposure to L2 results in less automated connections at the conceptual level, but this warrants further investigation.

13. Experiment 3 (L2–L1 priming) results and discussion

In Experiment 3, primes were presented in participants' L2 (Spanish) and targets were presented in their L1 (English).

13.1. Results

Data from one participant from the EB group were excluded due to low accuracy (<70%). Also, reaction times faster than 200 ms or slower than 2000 ms were discarded, which accounted for 3.0% of the whole data.

Average Lextale-Esp scores were 56.5 (SD = 12.37) for the EB group and 59.0 (10.75) for the LB group, with no significant difference between groups ($t(133.79) = -1.22$, $p = 0.226$).

Table 5 shows by subject accuracies and reaction times for each condition. The logistic regression model indicated that accuracies were higher for Related primes in Prefix condition than Unrelated primes (*Odds ratio* = 1.537, 95% CI = [1.154, 2.045], $p = 0.003$), and this effect did not interact with Group (*Odds ratio* = 0.833, 95% CI = [0.509, 1.365], $p = 0.469$). Post-hoc analysis that examined this effect separately for each group indicated statistical insignificance for both the EB group (*Odds ratio* = 1.350, 95% CI = [0.970, 1.880], $p = 0.075$) and the LB group (*Odds ratio* = 1.689, 95% CI = [0.935, 3.050], $p = 0.082$).

Reaction times are plotted in Figure 1C. We observe statistically significant Prefix priming effects with the main effect of Relatedness ($\beta = 0.039$, 95% CI = [0.017, 0.061], $p < 0.001$) that are statistically larger than Identity priming effects (Relatedness × Condition1; $\beta = -0.031$, 95% CI = [−0.061, −0.001], $p = 0.042$), but these effects are not dissociable from Orthographic or Semantic priming effects as Relatedness does not interact with Condition 2 ($\beta = 0.012$, 95% CI = [−0.039, 0.063], $p = 0.650$) or Condition 3 ($\beta = 0.023$, 95% CI = [−0.028, 0.073], $p = 0.377$). Reaction times were also faster for short target ($\beta = -0.020$, 95% CI = [−0.033, 0.006], $p = 0.004$) and prime words ($\beta = -0.007$, 95% CI = [−0.012, −0.002], $p = 0.009$). There are no significant interactions concerning Group ($p > 0.209$).

In the post-hoc analysis, the EB group showed statistically reliable Prefix priming effects ($\beta = -0.042$, 95% CI = [0.012, 0.072], $p = 0.006$), but these effects did not differ from Orthographic priming effects ($\beta = -0.030$, 95% CI = [−0.072, 0.013], $p = 0.169$) and Semantic priming effects ($\beta = -0.040$, 95% CI = [−0.082, 0.001], $p = 0.055$). Also, other conditions (Identity, Orthography and Semantic) did not show statistically significant priming effects (all $p < 0.240$). The LB group showed a similar pattern: Prefix condition had statistically reliable priming effects ($\beta = 0.036$, 95% CI = [0.009, 0.064], $p = 0.010$), but did not differ from priming effects in Orthography or Semantic conditions (all $p > 0.164$). No statistically reliable priming effects were found in other conditions (all $p < 0.164$).

In summary, both the EB group and the LB group showed facilitatory priming effects in Prefix condition, but these effects were not statistically dissociable from priming effects stemming from Orthographic or Semantic overlap.

13.2. Discussion

In Experiment 3, prefix priming was investigated from participants' L2 to L1. Unlike Experiment 2, cross-language prefix priming effects for the EB group are not statistically dissociated from orthographic priming effects, nor do translation equivalents show robust priming effects. The LB group showed a similar pattern, where priming effects for Prefix and Orthography conditions do not interact. Given the similar Levenshtein distance between related versus unrelated prime words and target words in Prefix and Orthography condition, the absence of interaction leaves it unclear whether the observed prefix priming effects are purely

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morphological or are due to form overlap. Taking together the results from Experiments 2 and 3, we find asymmetry in both Identity and Prefix priming effects for the EB group, where the priming effects are reliable in the L1–L2 direction but not in the L2–L1 direction.

Asymmetric priming effects for translation equivalents (Identity condition in the current study) align with previous studies (e.g., Jiang, 1999; Smith et al., 2019; Wang, 2013). Models of the bilingual lexicon provide explanations for such asymmetry that are based on weaker representations of L2 primes, either because they have less substantial connections to concepts (RHM) or they are harder to recognize due to low resting activation level (BIA, BIA+). Another explanation comes from Smith et al. (2019), who attribute the asymmetry to L2 targets having more room for priming due to their overall slower response times. In that study, L2–L2 identity priming yielded larger priming effects than L1–L1 identity priming among unbalanced Hebrew-English bilinguals with mean AoA of 6.5. The authors also observed larger priming effects of translation equivalents for L1–L2 than L2–L1. If the stronger connection of L1 words to concepts is the only factor for the asymmetry, then L1–L1 identity priming effects should be larger than L2–L2 identity priming. Therefore, the results suggest that relatively lower resting levels of L2 targets also play a role in the asymmetry — because L2 words are generally less activated for unbalanced bilinguals, they benefit more from priming. While these findings provide a convincing explanation for the asymmetry, it remains to be tested whether the early bilinguals with younger AoA as in the current study (less than 5) also have lower resting levels for L2 than L1 words.

As for prefixes, there are two possible reasons for the lack of purely morphological priming effects in the L2–L1 direction for both early bilinguals and late bilinguals. It can either be the case that prefixes in L2 primes are identified but do not prime those in L1 as is the case for translation equivalents, or they are not identified in the first place, especially when they are only briefly presented (50 ms in the current experiment). In Experiment 4, we aim to tease apart these two possibilities by testing prefix priming effects within participants' L2. If prefixes in L2 masked primes are identified, we expect to find robust prefix priming effects, thereby rejecting the second possibility.

14. Experiment 4 (L2–L2 priming) results and discussion

Experiment 4 tested prefix priming within one's L2. Therefore, both primes and targets were presented in Spanish.

14.1. Results

One participant from the EB group and seven participants from the LB group were removed due to low accuracy rates (<70%). Five items with low accuracy rates (<50%) as well as reaction times faster than 200 ms or slower than 2000 ms were also excluded from data analysis. The data removal based on the reaction times accounted for 14.6% of the data.

The mean scores for Lextale-Esp were 58.1 (SD = 13.95) for the EB group and 58.1 (14.97) for the LB group. The difference between groups was not statistically significant ($t(142.24) = -0.02$, $p = 0.982$).

See Table 5 for by subject accuracy rates and mean RTs. Reaction times are also plotted in Figure 1D. Analysis on accuracy data revealed no statistically reliable effect of Group, Condition, or Relatedness (all $p > 0.190$).

The output of the linear mixed effects regression model for reaction times showed statistically reliable Prefix priming effects ($\beta = -0.025$, 95% CI = [−0.050, −0.000], $p = 0.046$) but these effects did not differ from other priming effects including Orthography (Relatedness × Condition 2; $\beta = 0.020$, 95% CI = [−0.011, 0.051], $p = 0.210$) and Semantic (Relatedness × Condition 3; $\beta = 0.019$, 95% CI = [−0.012, 0.049], $p = 0.227$) condition. In addition, target frequency ($\beta = -0.073$, 95% CI = [−0.099, −0.046], $p < 0.001$) and target length ($\beta = 0.032$, 95% CI = [0.023, 0.044], $p < 0.001$) had reliable effects on the reaction times.

Post-hoc analyses examined priming effects separately for each group. The EB group showed statistically significant Identity priming effects ($\beta = -0.026$, 95% CI = [−0.050, −0.002], $p = 0.035$) but not Prefix priming effects ($\beta = -0.029$, 95% CI = [−0.063, 0.004], $p = 0.086$). Orthography and Semantic conditions did not show statistically significant priming effects (all $p < 0.732$). For the LB group, none of the priming effects in the four conditions reached statistical significance (all $p > 0.096$).

14.2. Discussion

In Experiment 4, prefix priming within one's non-dominant language was examined. The results indicate that prefix priming effects for both the EB and the LB groups are not statistically reliable, indicating that they may not be able to rapidly identify prefixes in multimorphemic words that are visually presented very briefly in their less dominant language. This result further suggests that the prefix priming effects observed in Experiment 3 may be more likely due to form and/or semantic overlap between prime and target words than morphological overlap.

The current results show that prefixes do not yield robust masked priming effects in one's less dominant language in contrast to the results from one's dominant language (Experiment 1). These results also contrast with L2 root priming studies (e.g., Diependaele et al., 2011) that report robust morphological root priming effects in participants' L2 (e.g., *viewer*-VIEW). In short, bilinguals with an intermediate-level L2 proficiency may not be able to identify prefixes as opposed to roots in masked L2 complex words, regardless of their AoA. These results are in line with the Word and Affix model proposed in Beyersmann and Grainger (2023) according to which the processing mechanism of affixes is distinct from that of roots as affixes, but not roots, are subject to positional constraints. In this sense, the development of processing affixes may be slower than that of roots similar to L1 morphological development among young children (e.g., Dawson et al., 2018; Hasenäcker et al., 2020). Future studies may examine whether L2 speakers with higher proficiency than those in the current study show robust prefix priming in their L2 to determine whether increased proficiency enhances affix processing.

Results thus far from each experiment have been analyzed separately. The next section quantifies the relative size of prefix priming effects per experiment and per group in a single linear mixed effects model.

15. Comparison of prefix priming between experiments

Qualitatively comparing significant versus non-significant results does not entail a statistically reliable interaction (e.g., Gelman and Stern, 2006). Thus, to better evaluate the similarities and differences across experiments we fit a linear mixed effects model that aggregates Prefix data from Experiments 2, 3, and 4. This allows us to examine whether the magnitude of prefix priming across the experiments and groups is different. Data from Experiment 1 were

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not included in this analysis because they do not have the group factor. The statistical model included Relatedness (Related versus Unrelated), Experiment (Experiment 2, 3, or 4), and Group (EB or LB) and their interactions as fixed effect and Target word frequency, Prime word frequency, Target word length, and Prime word length as covariates. Binary and continuous factors were centered. The factor Experiment was coded using simple contrast coding with Experiment 2 as reference, such that the intercept is the grand mean of all the three experiments, while the two contrasts compare Experiment 2 and Experiment 3, and Experiment 2 and Experiment 4, respectively. The most complex random effects that converged included random slopes for Relatedness and random intercepts for both participant and item.

The results showed statistically reliable main effect of Relatedness ($\beta = -0.037$, 95% CI = $[-0.063, -0.012]$, $p = 0.004$), which means that prefix priming effects are robust across the three experiments and two groups. The two-way interactions between Relatedness and Experiment 2 versus 3 and Relatedness and Experiment 2 versus 4 were not statistically significant (all $p > 0.431$), indicating that the size of prefix priming effects is not statistically dissociable between Experiment 2 and Experiment 3 and between Experiment 2 and Experiment 4.

16. General discussion

The main goal of the current study was to examine the representation of prefixes within and across L1 and L2 using the masked priming paradigm. In Experiment 1, we replicated robust prefix priming in one's dominant language as reported in previous studies (Ciaccio et al., 2020; Chateau et al., 2002; Dominguez, 2006, 2010; Giraudo and Grainger, 2003). Priming effects of orthographic or semantic overlap, on the other hand, are not statistically reliable, indicating that priming effects of prefixes cannot be attributed to those factors. In other words, in one's dominant language, prefixes form independent representation units in the mental lexicon that are not reduced to orthographic or semantic relations, and these units facilitate subsequent access as do roots. These results provide a foundation to probe prefix priming across different languages (Experiment 2 and Experiment 3) and within one's less dominant language (Experiment 4). The rest of this section discusses the results from Experiment 2–4. Separate analyses in each experiment suggest that prefix priming effects are less reliable and not dissociable from orthographic priming in certain situations. When aggregating across experiments however we do not find significant interactions with experiment. We therefore proceed to discuss these apparent patterns with caution.

17. Cross-language prefix priming

Experiment 2 tested prefix priming in the L1–L2 direction, where primes and targets are in different languages but share prefixes that have the same form and meaning. Experiment 3 tested the same effect in the opposite L2–L1 direction. While the comparison between experiments indicates no significant difference in the size of prefix priming between Experiments 2 and 3, separate analyses for the two experiments show that for early bilinguals, these cognate prefixes are primed independently from orthographic overlap when primes are presented in L1, but not when primes are presented in L2. Late bilinguals, on the other hand, do not show evidence of purely morphological priming effects in either direction.

To our knowledge, this is the first time to show cross-language prefix priming effects in the L1-L2 direction. These results suggest that among the early bilinguals, cognate prefixes are mapped onto a shared representation. While we do not attempt to tease apart the two bilingual models introduced in the Introduction (RHM and BIA+), we acknowledge that this claim has different implications for each model when implemented. Within the framework of RHM, this can be explained by postulating that prefixes are represented in the same way as monomorphemic words; those cognate prefixes in L1 and L2 are connected by lexical links and also are connected to a single concept node by conceptual links. When an L1 prefixed word is encountered, for example, it is decomposed into a prefix and a root, each of which then activates its linked concept and L2 counterpart, enabling cross-linguistic prefix priming as well as root priming. According to the BIA+, cognate prefixes in the two languages are connected at the orthographic and semantic levels. Within this framework, the consistent mapping of form and meaning of these prefixes in the two languages yield between-languages prefix priming without a separate process of decomposition.

The results are also in line with previous literature on language transfer, specifically of morphology (Marks et al., 2023; Ramírez et al., 2011; Wang et al., 2022), and convergence (Baptista et al., 2016; Muysken, 2000, 2013; Weinreich, 1953). For instance, in Ramírez et al. (2011), English learners with L1 Spanish and those with L1 Chinese outperformed each other on the component of English morphology that is similar to their L1: derivational morphology for Spanish learners of English and compounds for Chinese learners of English.

In a similar vein, according to the convergence hypothesis, particularly the isomorphic hypothesis, the features that are common in the two languages are prioritized and learned faster (Muysken, 2000, 2013; Weinreich, 1953). One piece of supporting evidence for this hypothesis comes from Baptista et al. (2016), where English speakers learned an artificial language. After one session of a learning phase, participants who were exposed to an artificial language that have morphemes similar to English ("nat" for negation and "iss" for plurality) produced them more accurately than those exposed to the reverse condition ("iss" for negation and "nat" for plurality) and the novel condition ("plick" for negation and "mut" for plurality). This suggests that L2 morphemes that have a similar form and function to those in L1 may map onto them, thus gaining advantage during the learning process.

One crucial point worth noting is that the cognate prefix priming reported in the study is seemingly contradictory with prior results for cognate root priming, which was not dissociable from orthographic priming between Hebrew and French (Voga and Grainger, 2007). However, the participants in Voga and Grainger (2007) come from populations more similar to late bilinguals than early bilinguals in the current study based on the description that they were "taught French as a second language during school years (p. 940)." Future research with early bilinguals is necessary to examine whether they show reliable cognate root priming effects that are greater than form based priming effects.

In short, by using the priming paradigm with bilinguals, the present study provides more direct evidence that such morphemes form shared morphological representation among individuals who acquired two languages in a naturalistic setting. On the other hand, the early bilingual group did not show reliable prefix priming effects in L2–L1 direction (Experiment 3). The lack of its interaction with those in the L1–L2 direction (Experiment 2) calls for careful interpretation. Yet, the results from Experiment 4 where participants did not show uniquely morphological L2–L2 prefix priming effects

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suggests that such asymmetry arises because early bilinguals are not able to rapidly identify prefixes from L2 masked words. Nevertheless, it is also possible that even when L2 words are presented for sufficient time, cross-language prefix priming effects are not observed, which would then indicate that prefixes, even when fully recognized, do not prime in the L2–L1 direction. Such asymmetry is predicted by the discussed bilingual models, if we assume that prefixes are represented in a similar way to words (i.e., RHM: weaker conceptual links between L2 prefix and concept, BIA+: lower resting levels of L2 prefixed words). Further research would be necessary to test this possibility.

We do not observe any reliable cross-language prefix priming effects from the late bilinguals, both in the L1–L2 and L2–L1 directions. These results, especially in the L1–L2 direction, contrast with some assumptions of prominent models of the bilingual lexicon, specifically that novice bilinguals will show a stronger asymmetry in cross-language priming. With the current method that requires very fast recognition of prefixes in L2 words in order for any priming to occur, the results suggest that late bilinguals may struggle to achieve the same level of prefix recognition as early bilinguals (c.f., Babcock et al., 2012; Basnight-Brown and Altarriba, 2007; Veríssimo et al., 2018). One limitation of this method is that it does not rule out the possibility that late bilinguals show cross-languages prefix priming effects when they are allowed sufficient time to process prefixes. Therefore, it may be premature to conclude solely from the current study that cognate prefixes are stored completely separately for late bilinguals. Implementing a research design that complements the current methods, such as presenting prime words for longer duration or using a long-lag priming paradigm where participants perform a lexical decision task on prime words as well, would be a useful next step.

Finally, although the current results suggest differences between early bilinguals and late bilinguals in the way they process cognate prefixes, factors other than age of acquisition may also contribute to the difference. While the L2 proficiency measured by Lextale-Esp is comparable between the two groups across the three experiments, the amount of L2 daily use is significantly greater for early bilinguals than late bilinguals in all three experiments (all $p < 0.001$). This may be in part inevitable as half of the early bilinguals (52%) in the current study reported to be heritage Spanish speakers and thus listed family members or parents as their primary source of Spanish education, whereas only three late bilinguals were in this category. Most late bilinguals (87%) reported that they learned Spanish from school, private institute, or tutoring. A study that compares late bilinguals with different percentage of L2 daily use, such as those living in English speaking countries and those living in Spanish speaking countries, would be able to disentangle the effects of age of acquisition from language exposure.

18. L2 prefix priming

In addition to between-languages prefix priming, we also tested within-language prefix priming in one's dominant language (Experiment 1) and in one's less dominant language (Experiment 4) to examine whether the latter case also yields reliable priming effects. In contrast to robust prefix priming effects found in Experiment 1, these effects were not observed in Experiment 4 for both early bilinguals and late bilinguals.

As in the case of Experiment 3, however, the statistical comparison of effect sizes across experiments did not reveal statistically significant interaction of priming effects between Experiment 2 and Experiment 4, which again warrants caution in interpreting the results. Keeping that in mind, we tentatively suggest that these findings indicate that the processing mechanisms of prefixes may be different in L1 versus L2. This is partially similar to what Heyer and Clahsen (2015) report on the processing of derived words by L1 versus L2 speakers. In their study, in contrast to L1 speakers who showed priming effects only for morphological overlap (e.g., darkness – DARK), L2 speakers showed priming effects for both morphological overlap and orthographic overlap (e.g., example – EXAM). These results are interpreted as L2 learners' higher reliance on the orthographic relationship than the morphological relationship when processing morphologically complex L2 words. While the current results are similar to that study in that purely morphological L2 priming effects are not observed, they are different in the sense that we did not find orthographic priming effects, either. One possible reason for such discrepancy is that the stimuli in Orthography condition in the current study have a smaller number of overlapping letters (2–3 letters) compared to those used in Heyer and Clahsen (2015) (3–7 letters).

19. Conclusion

In summary, we tested prefix priming within and between languages across four experiments: L1-L1 (Experiment 1), L1–L2 (Experiment 2), L2–L1 (Experiment 3), and L2–L2 (Experiment 4) with AoA as a modulating factor. Following the robust prefix priming effects within one's L1 observed in Experiment 1, a key finding of the current study is comparable prefix priming effects from one's L1 to L2 by early bilinguals (Experiment 2). Such effects were not dissociated from orthographic priming in the L2–L1 direction and not observed within their L2. We also find an effect of AoA and possibly the percentage of L2 daily use on cross-language prefix priming as late bilinguals did not show robust prefix priming in any of the directions as well as within the L2. Based on these results, we conclude that cognate prefixes map onto the same representation for early bilinguals, but possibly not for late bilinguals.

Supplementary material. To view supplementary material for this article, please visit http://doi.org/10.1017/S136672892400107X.

Data availability statement. Data and analysis codes are available at https://osf.io/sg7zp/?view_only=d1502f38bda44e0ab500228c989863cf. This study was not preregistered.

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References

Amenta, S., & **Crepaldi, D.** (2012). Morphological processing as we know it: An analytical review of morphological effects in visual word identification. *Frontiers in Psychology*, **3**, 232.

Angele, B., **Baciero, A.**, **Gomez, P.**, & **Perea, M.** (2022) Does online masked priming pass the test? The effects of prime exposure duration on masked identity priming. *Behavioral Research Methods*, **55**, 151–167.

Babcock, L., **Stowe, J. C.**, **Maloof, C. J.**, **Brovetto, C.**, & **Ullman, M. T.** (2012). The storage and composition of inflected forms in adult-learned second language: A study of the influence of length of residence, age of arrival, sex, and other factors. *Bilingualism: Language and Cognition*, **15**(4), 820–840.

Balota, D. A., **Yap, M. J.**, **Hutchison, K. A.**, **Cortese, M. J.**, **Kessler, B.**, **Loftis, B.**, **Neely, J. H.**, **Nelson, D. L.**, **Simpson, G. B.**, & **Treiman, R.** (2007). The English Lexicon Project. *Behavior Research Methods*, **39**(3), 445–459. https://doi.org/10.3758/bf03193014

Basnight-Brown, D. M., & **Altarriba, J.** (2007). Differences in semantic and translation priming across languages: The role of language direction and language dominance. *Memory & Cognition*, **35**(5), 953–965.

Bates, D., **MächCer, M.**, **Bolker, B.**, & **Walker, S.** (2015). Fitting Linear Mixed-Effects Models Using lme4. *Journal of Statistical Software*, **67**(1), 1–48.

Baptista, M., **Gelman, S. A.**, & **Beck, E.** (2016). Testing the role of convergence in language acquisition, with implications for creole genesis. *International Journal of Bilingualism*, **20**(3), 269–296.

Beyersmann, E. & **Grainger, J.** (2023). The Role of Embedded Words and Morphemes in Reading. In D. Crepaldi (Ed.), *Linguistic Morphology in the Mind and Brain* (pp. 26–49). Routledge.

Birdsong, D. (2009). Interpreting age effects in second language acquisition. In J. F. Kroll & A. M. B. de Groot (Eds.), *Handbook of bilingualism: Psycholinguistic approaches* (pp. 109–127). Oxford University Press.

Birdsong, D. (2018). Plasticity, variability and age in second language acquisition and bilingualism. *Frontiers in Psychology*, **9**, 81.

Box, G. E. P. and Cox, D. R. (1964). An analysis of transformations. *Journal of the Royal Statistical Society*, **26**, 211–252.

Caramazza, A., & **Brones, I.** (1979). Lexical access in bilinguals. *Bulletin of the Psychonomic Society*, **13**(4), 212–214.

Cayado, D. K. T., **Wray, S.**, & **Stockall, L.** (2023). Does linear position matter for morphological processing? Evidence from a Tagalog masked priming experiment. *Language, Cognition and Neuroscience*, **38**(8), 1167–1182.

Chateau, D., **Knudsen, E. V.**, & **Jared, D.** (2002). Masked priming of prefixes and the influence of spelling–meaning consistency. *Brain and Language*, **81**(1–3), 587–600.

Cho, J., **Pires, A.**, & **Brennan, J. R.** (2024). How large are root and affix priming effects in visual word recognition? Estimation from original data and a Bayesian meta-analysis. *Language, Cognition and Neuroscience*, 1–19.

Ciaccio, L. A., **Kgolo, N.**, & **Clahsen, H.** (2020). Morphological decomposition in Bantu: A masked priming study on Setswana prefixation. *Language, Cognition and Neuroscience*, **35**(10), 1257–1271. https://doi.org/10.1080/23273798.2020.1722847

Clahsen, H. & **Felser, C.** (2006). Grammatical processing in language learners. *Applied Psycholinguistics*, **27**, 3–42.

Clahsen, H., **Felser, C.**, **Neubauer, K.**, **Sato, M.**, & **Silva, R.** (2010). Morphological Structure in Native and Nonnative Language Processing: Part of a special issue on Second Language Morphosyntax. *Language Learning*, **60**(1), 21–43.

Crepaldi, D., **Hemsworth, L.**, **Davis, C. J.**, & **Rastle, K.** (2015). Masked suffix priming and morpheme positional constraints. *Quarterly Journal of Experimental Psychology*, **69**(1), 113–128.

Davies, M. (2004) *British National Corpus* (from Oxford University Press). Available online at https://www.english-corpora.org/bnc/.

Davis, C., **Sánchez-Casas, R.**, **García-Albea, J. E.**, **Guasch, M.**, **Molero, M.**, & **Ferré, P.** (2010). Masked translation priming: Varying language experience and word type with Spanish–English bilinguals. *Bilingualism: Language and Cognition*, **13**(2), 137–155.

Dawson, N., **Rastle, K.**, & **Ricketts, J.** (2018). Morphological effects in visual word recognition: Children, adolescents, and adults. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, **44**(4), 645–654.

De Groot, A. M., & **Nas, G. L.** (1991). Lexical representation of cognates and noncognates in compound bilinguals. *Journal of Memory and Language*, **30**(1), 90–123.

Diependaele, K., **Duñabeitia, J. A.**, **Morris, J.**, & **Keuleers, E.** (2011). Fast morphological effects in first and second language word recognition. *Journal of Memory and Language*, **64**(4), 344–358.

Dijkstra, T., **Miwa, K.**, **Brummelhuis, B.**, **Sappelli, M.**, & **Baayen, H.** (2010). How cross-language similarity and task demands affect cognate recognition. *Journal of Memory and Language*, **62**(3), 284–301.

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

Dijkstra, T., **Van Jaarsveld, H.**, & **Ten Brinke, S.** (1998). Interlingual homograph recognition: Effects of task demands and language intermixing. *Bilingualism: Language and Cognition*, **1**(1), 51–66.

Domínguez, A., **Alija, M.**, **Cuetos, F.**, & **de Vega, M.** (2006). Event related potentials reveal differences between morphological (prefixes) and phonological (syllables) processing of words. *Neuroscience Letters*, **408**(1), 10–15.

Dominguez, A., **Alija, M.**, **Rodriguez-Ferreiro, J.**, & **Cuetos, F.** (2010). The contribution of prefixes to morphological processing of Spanish words. *European Journal of Cognitive Psychology*, **22**(4), 569–595.

Ferré, P., & **Brysbaert, M.** (2017). Can Lextale-Esp discriminate between groups of highly proficient Catalan–Spanish bilinguals with different language dominances?. *Behavior Research Methods*, **49**, 717–723.

Foote, R., **Qasem, M.** & **Trentman, E.** (2020). Morphological decomposition in L2 Arabic: A masked priming study. *Journal of Psycholinguist Research*, **49**, 291–317.

Forster, K. I., & **Davis, C.** (1984). Repetition priming and frequency attenuation in lexical access. *Journal of Experimental psychology: Learning, Memory, and Cognition*, **10**(4), 680.

Gelman, A., & **Stern, H.** (2006). The difference between "significant" and "not significant" is not itself statistically significant. *The American Statistician*, **60**(4), 328–331.

Giraudo, H., & **Grainger, J.** (2003). On the role of derivational affixes in recognizing complex words: Evidence from masked priming. In H. Baayen & R. Schreuder (Eds.), *Morphological Structure in Language Processing* (pp. 209–232). The Hague: Mouton.

Grainger, J., & **Frenck-Mestre, C.** (1998). Masked priming by translation equivalents in proficient bilinguals. *Language and Cognitive Processes*, **13**, 601–623.

Hasenäcker, J., **Beyersmann, E.**, & **Schroeder, S.** (2020). Morphological Priming in Children: Disentangling the Effects of School-grade and Reading Skill. *Scientific Studies of Reading*, **24**(6), 484–499.

Heyer, V., & **Clahsen, H.** (2015). Late bilinguals see a scan in scannerAND in scandal: Dissecting formal overlap from morphological priming in the processing of derived words. *Bilingualism: Language and Cognition*, **18**(3), 543–550.

Hopp, H., & **Grüter, T.** (2023). The time-course of competition from the L1 grammar in L2 sentence processing: evidence from cross-linguistic structural priming. *Second Language Research*, **39**(1), 133–159.

Izura, C., **Cuetos, F.**, & **Brysbaert, M.** (2014). Lextale-Esp: A test to rapidly and efficiently assess the Spanish vocabulary size. *Psicológica*, **35**, 49–66.

Jared, D., **Jouravlev, O.**, & **Joanisse, M. F.** (2017). The effect of semantic transparency on the processing of morphologically derived words: Evidence from decision latencies and event-related potentials. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, **43**(3), 422.

Jiang, N. (1999). Testing processing explanations for the asymmetry in masked cross-language priming. *Bilingualism: Language and Cognition*, **2**(1), 59–75.

Johnson, J. S., & **Newport, E. L.** (1989). Critical period effects in second language learning: The influence of maturational state on the acquisition of English as a second language. *Cognitive Psychology*, **21**(1), 60–99.

Keuleers, E., & **Brysbaert, M.** (2010). Wuggy: A multilingual pseudoword generator. *Behavior Research Methods*, **42**(3), 627–633.

Kim, S. Y., **Wang, M.**, & **Ko, I. Y.** (2011). The processing of derivational morphology in Korean–English bilingual readers. *Bilingualism: Language and Cognition*, **14**(4), 473–488.

Kim, S. Y., & **Wang, M.** (2014). The time-course of cross-language morphological activation in Korean-English bilinguals: Evidence from a masked priming experiment. *Language Research*, **50**(1), 59–75.

Kirsner, K., **Brown, H. L.**, **Abrol, S.**, **Chadha, N. K.**, & **Sharma, N. K.** (1980). Bilingualism and lexical representation. *The Quarterly Journal of Experimental Psychology*, **32**(4), 585–594.

Kotz, S.A. 2001: Neurolinguistic evidence for bilingual language representation: a comparison of reaction times and event-related brain potentials. *Bilingualism: Language and Cognition* **4**, 143–54.

Kotz, S. A., & **Elston-Güttler, K.** (2004). The role of proficiency on processing categorical and associative information in the L2 as revealed by reaction times and event-related brain potentials. *Journal of Neurolinguistics*, **17**(2), 215–235.

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., & **Tokowicz, N.** (2001). The development of conceptual representation for words in a second language. *One Mind, Two Languages: Bilingual Language Processing*, **2**, 49–71.

Kroll, J. F., & **Tokowicz, N.** (2005). Models of Bilingual Representation and Processing: Looking Back and to the Future. In J. F. Kroll & A. M. B. de Groot (Eds.), *Handbook of Bilingualism: Psycholinguistic approaches* (pp. 531–553). Oxford University Press.

Lemhöfer, K., & **Broersma, M.** (2012). Introducing LexTALE: A quick and valid lexical test for advanced learners of English. *Behavior Research Methods*, **44**, 325–343.

Lenneberg, E. H. (1967). The biological foundations of language. *Hospital Practice*, **2**(12), 59–67.

Lenth, R (2023). *emmeans: Estimated Marginal Means, aka Least-Squares Means.* R package version 1.8.5, https://CRAN.R-project.org/package=emmeans.

Long, M. H. (1990). Maturational constraints on language development. *Studies in Second Language Acquisition*, **12**(3), 251–285.

Lüdecke D, **Ben-Shachar M**, **Patil I**, **Makowski D** (2020). Extracting, computing and exploring the parameters of statistical models using R. *Journal of Open Source Software*, **5**(53), 2445.

Marian, V., **Bartolotti, J.**, **Chabal, S.**, **Shook, A.** (2012). CLEARPOND: Cross-linguistic easy-access resource for phonological and orthographic neighborhood densities. *PLoS One*, **7**(8): e43230.

Marks, R. A., **Labotka, D.**, **Sun, X.**, **Nickerson, N.**, **Zhang, K.**, **Eggleston, R. L.**, **Yu, C.-L.**, **Uchikoshi, Y.**, **Hoeft, F.**, & **Kovelman, I.** (2023). Morphological awareness and its role in early word reading in English monolinguals, Spanish–English, and Chinese–English simultaneous bilinguals. *Bilingualism: Language and Cognition*, **26**(2), 268–283.

Meade, G., **Grainger, J.**, & **Holcomb, P. J.** (2022). Language dominance modulates transposed-letter N400 priming effects in bilinguals. *Journal of Cognition*, **5**(1), 12.

Muysken, P. (2000). *Bilingual speech*. Cambridge, UK: Cambridge University Press.

Muysken, P. (2013). Language contact outcomes as the result of bilingual optimization strategies. *Bilingualism: Language and Cognition*, **16**(4), 709–730.

Pennington, J., **Socher, R.**, & **Manning, C. D.** (2014). Glove: Global vectors for word representation. In *Proceedings of the 2014 conference on empirical methods in natural language processing (EMNLP)* (pp. 1532–1543).

Plaut, D. C., & **Gonnerman, L. M.** (2000). Are non-semantic morphological effects incompatible with a distributed connectionist approach to lexical processing?. *Language and Cognitive Processes*, **15**(4–5), 445–485.

Ramirez, G., **Chen, X.**, **Geva, E.**, & **Luo, Y.** (2011). Morphological awareness and word reading in English language learners: Evidence from Spanish- and Chinese-speaking children. *Applied Psycholinguistics*, **32**(3), 601–618.

Rastle, K., **Davis, M. H.**, **Marslen-Wilson, W. D.**, & **Tyler, L. K.** (2000). Morphological and semantic effects in visual word recognition: A time-course study. *Language and Cognitive Processes*, **15**(4–5), 507–537.

Kenward, M. G., & **Roger, J. H.** (1997). Small sample inference for fixed effects from restricted maximum likelihood. *Biometrics*, 983–997.

Sabourin, L., **Brien, C.**, & **Burkholder, M.** (2014). The effect of age of L2 acquisition on the organization of the bilingual lexicon: Evidence from masked priming. *Bilingualism: Language and Cognition*, **17**(3), 542–555.

Schepens, J., **Dijkstra, T.**, & **Grootjen, F.** (2012). Distributions of cognates in Europe as based on Levenshtein distance. *Bilingualism: Language and Cognition*, **15**(1), 157–166.

Smith, Y., **Walters, J.**, & **Prior, A.** (2019). Target accessibility contributes to asymmetric priming in translation and cross-language semantic priming in unbalanced bilinguals. *Bilingualism: Language and Cognition*, **22**(1), 157–176.

Stevens, P., & **Plaut, D. C.** (2022). From decomposition to distributed theories of morphological processing in reading. *Psychonomic Bulletin & Review*, **29**(5), 1673–1702.

Van Heuven, W. J., **Dijkstra, T.**, & **Grainger, J.** (1998). Orthographic neighborhood effects in bilingual word recognition. *Journal of Memory and Language*, **39**(3), 458–483.

Venables, W. N, & **Reipley, B. D.** (2002). *Modern Applied Statistics with S*, 4th edition. Springer, New York.

Veríssimo, J., **Heyer, V.**, **Jacob, G.**, & **Clahsen, H.** (2018). Selective effects of age of acquisition on morphological priming: Evidence for a sensitive period. *Language Acquisition*, **25**(3), 315–326.

Voga, M., & **Grainger, J.** (2007). Cognate status and cross-script translation priming. *Memory and Cognition*, **35**, 938–952.

Wang, D., **Wang, S.**, **Zinszer, B.**, **Sheng, L.**, & **Jasińska, K.** (2022). Cross-linguistic influences of L1 on L2 morphosyntactic processing: An fNIRS study. *Journal of Neurolinguistics*, **63**, 101063.

Wang, X. (2013). Language dominance in translation priming: Evidence from balanced and unbalanced Chinese–English bilinguals. *Quarterly Journal of Experimental Psychology*, **66**(4), 727–743.

Weinreich, U. (1953). *Languages in contact: Findings and problems*. The Hague: Mouton.

Wen, Y., & **van Heuven, W. J.** (2017). Non-cognate translation priming in masked priming lexical decision experiments: A meta-analysis. *Psychonomic Bulletin & Review*, **24**, 879–886.

Yamashita, J., & **Jiang, N. A. N.** (2010). L1 influence on the acquisition of L2 collocations: Japanese ESL users and EFL learners acquiring English collocations. *Tesol Quarterly*, **44**(4), 647–668.

Appendix A. Stimuli used in Experiment 1

Condition	Related prime	Unrelated prime	Target
Identity	cut	sing	CUT
Identity	steal	dance	STEAL
Identity	shine	borrow	SHINE
Identity	rain	climb	RAIN
Identity	read	smoke	READ
Identity	hang	erase	HANG
Identity	eat	play	EAT
Identity	cry	jump	CRY
Identity	study	blow	STUDY
Identity	smell	ride	SMELL
Identity	thin	clean	THIN
Identity	wet	early	WET
Identity	sweet	heavy	SWEET
Identity	tall	wise	TALL
Identity	sad	light	SAD
Identity	good	itchy	GOOD
Identity	difficult	bright	DIFFICULT
Identity	young	calm	YOUNG
Identity	building	movie	BUILDING
Identity	ice	market	ICE
Identity	mouse	award	MOUSE
Identity	thief	soap	THIEF
Identity	finger	stairs	FINGER
Identity	sugar	wheel	SUGAR
Identity	door	rabbit	DOOR
Identity	sun	cotton	SUN
Identity	floor	hand	FLOOR
Identity	plane	letter	PLANE
Identity	rug	street	RUG
Identity	cheese	scissors	CHEESE
Prefix	distract	unbend	DISSUADE
Prefix	exhale	disprove	EXTEND
Prefix	interpret	upload	INTERVENE
Prefix	preside	unfold	PREPARE
Prefix	propose	entangle	PROCURE
Prefix	translate	seclude	TRANSPORT
Prefix	reunite	disallow	REFORM
Prefix	contravene	misspell	CONTRADICT
Prefix	connect	oversleep	CONVENE
Prefix	combine	malfunction	COMFORT
Prefix	antisocial	bemused	ANTIBIOTIC
Prefix	immune	misplace	IMPOSSIBLE

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(*Continued*)

Condition	Related prime	Unrelated prime	Target
Prefix	biweekly	unjust	BILINGUAL
Prefix	submissive	irregular	SUBORDINATE
Prefix	superficial	illiterate	SUPERIOR
Prefix	extravagant	malformed	EXTRAORDINARY
Prefix	insane	omniscient	INVALID
Prefix	homogeneous	unkind	HOMOSEXUAL
Prefix	equilibrium	nonfiction	EQUINOX
Prefix	panorama	midterm	PANDEMIC
Prefix	miniature	envelope	MINISKIRT
Prefix	monotone	circumstance	MONOPOLY
Prefix	metadata	symmetry	METAPHYSICS
Prefix	autograph	prejudice	AUTOMOBILE
Prefix	semicolon	introvert	SEMIFINALIST
Prefix	apolitical	ultrasound	ATHEISM
Prefix	cohort	tripod	COAUTHOR
Prefix	union	ex-wife	UNIFORM
Prefix	postwar	telephone	POSTSCRIPT
Prefix	centigram	misconduct	CENTIMETER
Orthography	ignite	smile	IGNORE
Orthography	hunch	agree	HUDDLE
Orthography	gamble	snort	GATHER
Orthography	trade	fold	TRACK
Orthography	cuddle	shock	CURTAIL
Orthography	halter	pinch	HAPPEN
Orthography	humiliate	slice	HURRY
Orthography	variate	place	VANISH
Orthography	visage	mourn	VISIT
Orthography	survive	growl	SUGGEST
Orthography	light	clumsy	LIBERAL
Orthography	tribal	polite	TRIVIAL
Orthography	candid	plain	CANNY
Orthography	amiable	muddy	AMPLE
Orthography	barbaric	cruel	BASIC
Orthography	furry	tense	FURTHER
Orthography	gothic	upset	GOLD
Orthography	simulated	terrible	SIMPLE
Orthography	assassin	caution	ASSUALT
Orthography	cubicle	method	CUISINE
Orthography	athlete	driver	ATTORNEY
Orthography	puberty	book	PUBLIC
Orthography	custom	moment	CUSHION
Orthography	goblet	security	GOAT
Orthography	candle	science	CANOPY

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(*Continued*)

Condition	Related prime	Unrelated prime	Target
Orthography	soap	drama	SOCIETY
Orthography	placebo	basis	PLAYER
Orthography	china	goal	CHILD
Orthography	mother	office	MOMENT
Orthography	photo	debt	PHONE
Semantic	publish	follow	WRITE
Semantic	lose	mourn	WIN
Semantic	rinse	blow	WASH
Semantic	run	grow	WALK
Semantic	delay	sound	WAIT
Semantic	elect	spend	VOTE
Semantic	greet	sow	HUG
Semantic	pull	shout	TURN
Semantic	attempt	smell	TRY
Semantic	faith	sting	TRUST
Semantic	hot	open	COLD
Semantic	slow	jealous	FAST
Semantic	thirsty	dull	HUNGRY
Semantic	harsh	honest	LENIENT
Semantic	strong	fancy	WEAK
Semantic	lovely	silly	BEAUTIFUL
Semantic	pair	bored	TWIN
Semantic	pure	curly	TRUE
Semantic	teeth	nature	MOUTH
Semantic	troops	video	WAR
Semantic	leg	story	ARM
Semantic	salt	freedom	PEPPER
Semantic	tree	child	LEAF
Semantic	queen	user	KING
Semantic	bird	office	EAGLE
Semantic	flower	chair	ROSE
Semantic	street	desk	CAR
Semantic	day	pouch	NIGHT
Semantic	clock	shirt	TIME
Semantic	glass	shoe	BOTTLE

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Appendix B. Stimuli used in Experiment 2

Condition	Related prime	Unrelated prime	Target
Identity	cut	sing	CORTAR
Identity	steal	dance	ROBAR
Identity	shine	claim	BRILLAR
Identity	rain	borrow	LLOVER
Identity	read	smoke	LEER
Identity	hang	erase	COLGAR
Identity	eat	play	COMER
Identity	cry	jump	LLORAR
Identity	study	glow	ESTUDIAR
Identity	smell	ride	OLER
Identity	thin	climb	NADAR
Identity	wet	paint	CORRER
Identity	sweet	heavy	DULCE
Identity	tall	wise	ALTO
Identity	sad	light	TRISTE
Identity	good	itchy	BUENO
Identity	difficult	bright	DIFÍCIL
Identity	young	calm	JOVEN
Identity	building	movie	EDIFICIO
Identity	ice	market	HIELO
Identity	mouse	award	RATÓN
Identity	thief	soap	LADRÓN
Identity	finger	stairs	DEDO
Identity	sugar	wheel	AZÚCAR
Identity	door	rabbit	PUERTA
Identity	sun	hand	SOL
Identity	floor	cotton	PISO
Identity	plane	letter	AVIÓN
Identity	rug	street	ALFOMBRA
Identity	cheese	tool	QUESO
Prefix	distract	unfold	DISGUSTAR
Prefix	exhale	disprove	EXPRIMIR
Prefix	intertwine	upload	INTERCALAR
Prefix	preview	unbend	PREDECIR
Prefix	provide	entangle	PROMETER
Prefix	translate	seclude	TRANSBORDAR
Prefix	rewash	distract	REHACER
Prefix	contravene	misspell	CONTRAPONER
Prefix	convene	oversleep	CONJUNTAR
Prefix	compress	malfunction	COMPLOT
Prefix	engrave	overestimate	ENCERRAR
Prefix	demote	anew	DECOMISAR

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(*Continued*)

Condition	Related prime	Unrelated prime	Target
Prefix	antislavery	bemused	ANTICUERPO
Prefix	impractical	outbound	IMBORABLE
Prefix	submissive	irrational	SUBSUELO
Prefix	superman	nonfiction	SUPERHERMOSA
Prefix	extramarital	apathetic	EXTRAFUERTE
Prefix	insane	omniscient	INCAPAZ
Prefix	homogeneous	unkind	HOMÓLOGO
Prefix	minicar	envelope	MINIFALDA
Prefix	megastore	circumstance	MEGACAMPO
Prefix	multitask	underscore	MULTICAPA
Prefix	autopilot	prejudice	AUTOGESTIÓN
Prefix	semicolon	introvert	SEMIDIFUNTO
Prefix	cohort	tripod	COAUTORÍA
Prefix	ultraleft	exwife	ULTRALIVIANO
Prefix	postwar	telephone	POSTEMBARAZO
Prefix	century	upgrade	CENTENAR
Prefix	biannual	monologue	BISEMANAL
Prefix	ecofriendly	overcooked	ECOALDEA
Orthography	ignite	smile	IGUALAR
Orthography	hunch	agree	HUNDIR
Orthography	gamble	snort	GANAR
Orthography	trade	fold	TRATAR
Orthography	cuddle	shock	CUMPLAR
Orthography	pinch	halter	PICAR
Orthography	solve	humiliate	SOPLAR
Orthography	variate	place	VACIAR
Orthography	visage	mourn	VISITAR
Orthography	survive	growl	SUBIR
Orthography	gargle	prompt	GASTAR
Orthography	build	climb	BUSCAR
Orthography	candid	plain	CANSADO
Orthography	amiable	muddy	AMARGO
Orthography	barbaric	cruel	BARATO
Orthography	furry	tense	FUERTE
Orthography	gothic	upset	GORDO
Orthography	simulated	terrible	SIMPÁTICO
Orthography	dubious	mean	DULCE
Orthography	assassin	caution	ASIGNATURA
Orthography	cubicle	method	CUADERNO
Orthography	athlete	driver	ATLETA
Orthography	puberty	book	PUEBLO
Orthography	custom	moment	CUESTIÓN
Orthography	goblet	security	GOBIERNO
Orthography	candle	science	CANTIDAD

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(*Continued*)

Condition	Related prime	Unrelated prime	Target
Orthography	placebo	basis	PLAYA
Orthography	china	bunch	CHANCHO
Orthography	mother	office	MOCHILA
Orthography	debt	apple	DENTISTA
Semantic	publish	follow	ESCRIBIR
Semantic	lose	mourn	GANAR
Semantic	rinse	blow	LAVAR
Semantic	run	grow	CAMINAR
Semantic	delay	sound	ESPERAR
Semantic	elect	spend	VOTAR
Semantic	greet	sow	ABRAZAR
Semantic	pull	shout	GIRAR
Semantic	attempt	smell	PROBAR
Semantic	faith	sting	CONFIAR
Semantic	seize	wink	TOMAR
Semantic	gulp	offer	TRAGAR
Semantic	thirsty	dull	HAMBRIENTO
Semantic	harsh	honest	INDULGENTE
Semantic	strong	fancy	DÉBIL
Semantic	lovely	silly	HERMOSO
Semantic	pair	bored	MELLIZO
Semantic	pure	curly	VERDADERO
Semantic	loose	dizzy	APRETADO
Semantic	teeth	nature	BOCA
Semantic	troops	video	GUERRA
Semantic	leg	story	BRAZO
Semantic	salt	freedom	PIMIENTA
Semantic	tree	child	HOJA
Semantic	queen	user	REY
Semantic	bird	office	PÁJARO
Semantic	street	desk	COCHE
Semantic	day	pouch	NOCHE
Semantic	clock	shirt	TIEMPO
Semantic	glass	shoe	BOTELLA

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Appendix C. Stimuli used in Experiment 3

Condition	Related prime	Unrelated prime	Target
Identity	cortar	bailar	CUT
Identity	robar	cantar	STEAL
Identity	brillar	partir	SHINE
Identity	llover	temer	RAIN
Identity	leer	fumar	READ
Identity	colgar	borrar	HANG
Identity	comer	jugar	EAT
Identity	llorar	saltar	CRY
Identity	estudiar	volar	STUDY
Identity	oler	viajar	SMELL
Identity	nadar	sabio	THIN
Identity	correr	pintar	WET
Identity	dulce	pesado	SWEET
Identity	alto	divertido	TALL
Identity	triste	ligero	SAD
Identity	bueo	azul	GOOD
Identity	difícil	brillante	DIFFICULT
Identity	joven	trepar	YOUNG
Identity	edificio	película	BUILDING
Identity	hielo	mercado	ICE
Identity	ratón	premio	MOUSE
Identity	ladrón	minuto	THIEF
Identity	dedo	agua	FINGER
Identity	azúcar	foto	SUGAR
Identity	puerta	mujer	DOOR
Identity	sol	algodón	SUN
Identity	piso	conejo	FLOOR
Identity	avión	carta	PLANE
Identity	alfombra	calle	RUG
Identity	queso	mano	CHEESE
Prefix	disentir	subrayar	DISTRACT
Prefix	exprimir	beneficiar	EXHALE
Prefix	intercalar	posponer	INTERTWINE
Prefix	predecir	superar	PREVIEW
Prefix	prometer	enredar	PROVIDE
Prefix	transbordar	envolver	TRANSLATE
Prefix	rehacer	dislocar	REWASH
Prefix	contraponer	entremeter	CONTRAVENE
Prefix	conjuntar	repetir	CONVENE
Prefix	complot	desatar	COMPRESS
Prefix	encerrar	colaborar	ENGRAVE
Prefix	deletrear	entregar	DEMOTE

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(*Continued*)

Condition	Related prime	Unrelated prime	Target
Prefix	anticuerpo	monopolio	ANTISLAVERY
Prefix	imborable	bendito	IMPRACTICAL
Prefix	subsuelo	irracional	SUBMISSIVE
Prefix	superhermosa	inactivo	SUPERMAN
Prefix	extrafuerte	desnudo	EXTRAMARITAL
Prefix	incapaz	apático	INSANE
Prefix	homólogo	subterráneo	HOMOGENUOUS
Prefix	minifalda	provida	MINICAR
Prefix	megacampo	proelección	MEGASTORE
Prefix	multicapa	entreacto	MULTITASK
Prefix	autogestión	bípedo	AUTOPILOT
Prefix	semidifunto	introvertido	SEMICOLON
Prefix	coautoría	trípode	COHORT
Prefix	ultraliviano	exesposa	ULTRALEFT
Prefix	postembarazo	teléfono	POSTWAR
Prefix	centenar	supermercado	CENTURY
Prefix	bisabuelo	monólogo	BIANNUAL
Prefix	ecoaldea	sobrecocido	ECOFRIENDLY
Orthography	igualar	volver	IGNORE
Orthography	hundir	aceptar	HUDDLE
Orthography	ganar	esnifar	GATHER
Orthography	tratar	doblar	TRACK
Orthography	cumplar	beber	CURTAIL
Orthography	hablar	pellizcar	HAPPEN
Orthography	humillar	picar	HURRY
Orthography	vaciar	buscar	VANISH
Orthography	visitar	llorar	VISIT
Orthography	subir	gruñir	SUGGEST
Orthography	limado	torpe	LIBERAL
Orthography	trabajado	educado	TRIVIAL
Orthography	cansado	negro	CANNY
Orthography	amargo	lodoso	AMPLE
Orthography	barato	violento	BASIC
Orthography	fuerte	tenso	FURTHER
Orthography	gordo	enfadado	GOLD
Orthography	simpático	pequeño	SIMPLE
Orthography	asterisco	copa	ASSUALT
Orthography	cuaderno	método	CUISINE
Orthography	atleta	conductor	ATTORNEY
Orthography	pueblo	momento	PUBLIC
Orthography	cuestión	libro	CUSHION
Orthography	gobierno	seguridad	GOAT
Orthography	cantidad	arte	CANOPY

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(*Continued*)

Condition	Related prime	Unrelated prime	Target
Orthography	sopa	cuenta	SOCIETY
Orthography	playa	crema	PLAYER
Orthography	chancho	meta	CHILD
Orthography	mochila	oficina	MOMENT
Orthography	documento	amigo	DOUBT
Semantic	escribir	llorar	PUBLISH
Semantic	ganar	seguir	LOSE
Semantic	lavar	soplar	RINSE
Semantic	caminar	crecer	RUN
Semantic	esperar	sonar	DELAY
Semantic	votar	gastar	ELECT
Semantic	abrazar	sembrar	GREET
Semantic	girar	gritar	PULL
Semantic	probar	oler	ATTEMPT
Semantic	confiar	picar	FAITH
Semantic	tomar	abierta	HOT
Semantic	tragar	honesta	SLOW
Semantic	hambriento	celoso	THIRSTY
Semantic	indulgente	tedioso	HARSH
Semantic	débil	lujosa	STRONG
Semantic	hermoso	tonto	LOVELY
Semantic	mellizo	aburrido	PAIR
Semantic	verdadero	ondulado	PURE
Semantic	boca	naturaleza	TEETH
Semantic	guerra	parada	TROOPS
Semantic	brazo	cuento	LEG
Semantic	pimienta	libertad	SALT
Semantic	hoja	niña	TREE
Semantic	rey	usuario	QUEEN
Semantic	águila	foto	BIRD
Semantic	rosa	silla	FLOWER
Semantic	coche	plato	STREET
Semantic	noche	bolsa	DAY
Semantic	tiempo	tren	CLOCK
Semantic	botella	zapato	GLASS

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Appendix D. Stimuli used in Experiment 4

Condition	Related prime	Unrelated prime	Target
Identity	cortar	bailar	CORTAR
Identity	robar	cantar	ROBAR
Identity	brillar	haber	BRILLAR
Identity	llover	venir	LLOVER
Identity	leer	fumar	LEER
Identity	colgar	borrar	COLGAR
Identity	comer	jugar	COMER
Identity	llorar	saltar	LLORAR
Identity	estudiar	brillar	ESTUDIAR
Identity	oler	montar	OLER
Identity	nadar	trepar	NADAR
Identity	correr	pintar	CORRER
Identity	dulce	pesado	DULCE
Identity	alto	sabio	ALTO
Identity	triste	ligero	TRISTE
Identity	bueno	picante	BUENO
Identity	difícil	brillante	DIFÍCIL
Identity	joven	calmo	JOVEN
Identity	edificio	película	EDIFICIO
Identity	hielo	mercado	HIELO
Identity	ratón	premio	RATÓN
Identity	ladrón	jabón	LADRÓN
Identity	dedo	escaleras	DEDO
Identity	azúcar	rueda	AZÚCAR
Identity	puerta	conejo	PUERTA
Identity	sol	mano	SOL
Identity	piso	algodón	PISO
Identity	avión	carte	AVIÓN
Identity	alfombra	calle	ALFOMBRA
Identity	queso	herramienta	QUESO
Prefix	distractir	ecoaldea	DISGUSTAR
Prefix	exhalar	refutar	EXPRIMIR
Prefix	interferir	subrir	INTERCALAR
Prefix	prever	desdoblar	PREDECIR
Prefix	proveer	enredar	PROMETER
Prefix	transcribir	aisalar	TRANSBORDAR
Prefix	relavar	distraer	REHACER
Prefix	contravenir	deshacer	CONTRAPONER
Prefix	convocar	oversleep	CONJUNTAR
Prefix	comprimir	aprender	COMPLOT
Prefix	entregar	sobreestimar	ENCERRAR
Prefix	degradar	reducir	DECOMISAR

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Condition	Related prime	Unrelated prime	Target
Prefix	antipático	confundido	ANTICUERPO
Prefix	impráctico	contrario	IMBORABLE
Prefix	subsiguiente	irracional	SUBSUELO
Prefix	superhombre	retroactivo	SUPERHERMOSA
Prefix	extraordinario	apático	EXTRAFUERTE
Prefix	inmóvil	omnisciente	INCAPAZ
Prefix	homogéneo	desagradable	HOMÓLOGO
Prefix	minicoche	extravío	MINIFALDA
Prefix	megatienda	desorden	MEGACAMPO
Prefix	multitarea	subrayar	MULTICAPA
Prefix	contrato	prejuicio	AUTOGESTIÓN
Prefix	semicírculo	introvertido	SEMIDIFUNTO
Prefix	cofundador	trípode	COAUTOR
Prefix	ultravioleta	exesposa	ULTRALIVIANO
Prefix	postdata	teléfono	POSTEMBARAZO
Prefix	centimetro	prejuicio	CENTENAR
Prefix	bianual	monólogo	BISEMANAL
Prefix	ecología	invasión	ECOSISTEMA
Orthography	ignorar	solicitar	IGUALAR
Orthography	hurtar	patear	HUNDIR
Orthography	granjear	bufar	GANAR
Orthography	traer	doblar	TRATAR
Orthography	cuidar	pisar	CUMPLAR
Orthography	pillar	riñonera	PICAR
Orthography	sonreir	humillar	SOPLAR
Orthography	valorar	colocar	VACIAR
Orthography	viajar	lamentar	VISITAR
Orthography	sujetar	gruñir	SUBIR
Orthography	galopar	incitar	GASTAR
Orthography	bullir	trepar	BUSCAR
Orthography	callado	sencillo	CANSADO
Orthography	amarillo	fango	AMARGO
Orthography	baldio	cruel	BARATO
Orthography	fugado	tenso	FUERTE
Orthography	goma	alterado	GORDO
Orthography	simplemente	terrible	SIMPÁTICO
Orthography	duradero	mezquino	DULCE
Orthography	asustado	delito	ASIGNATURA
Orthography	curioso	método	CUADERNO
Orthography	ataque	conductor	ATLETA
Orthography	punto	libro	PUEBLO
Orthography	cuento	momento	CUESTIÓN
Orthography	gourmet	seguridad	GOBIERNO

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Condition	Related prime	Unrelated prime	Target
Orthography	canguro	derrota	CANTIDAD
Orthography	placer	base	PLAYA
Orthography	chaleco	manojo	CHANCHO
Orthography	ciencia	oficina	MOCHILA
Orthography	depósito	manzana	DENTISTA
Semantic	publicar	v	ESCRIBIR
Semantic	perder	lamentar	GANAR
Semantic	enjuagar	soploar	LAVAR
Semantic	pasear	crecer	CAMINAR
Semantic	retrasar	sonar	ESPERAR
Semantic	elegir	gastar	VOTAR
Semantic	saludar	sembrar	ABRAZAR
Semantic	jalar	trotar	GIRAR
Semantic	intentar	hablar	PROBAR
Semantic	fiable	picar	CONFIAR
Semantic	agarrar	guiñar	TOMAR
Semantic	deglutir	ofrecer	TRAGAR
Semantic	sediento	aburrido	HAMBRIENTO
Semantic	áspero	honesto	INDULGENTE
Semantic	fuerte	fantasioso	DÉBIL
Semantic	encantador	tonto	HERMOSO
Semantic	par	aburrido	MELLIZO
Semantic	puro	rízado	VERDADERO
Semantic	flojo	mareado	APRETADO
Semantic	dientes	naturaleza	BOCA
Semantic	tropas	vídeo	GUERRA
Semantic	pierna	historia	BRAZO
Semantic	sal	libertad	PIMIENTA
Semantic	árbol	niño	HOJA
Semantic	árbol	usuario	REY
Semantic	flor	oficina	ROSA
Semantic	calle	escritorio	COCHE
Semantic	día	bolsa	NOCHE
Semantic	reloj	camisa	TIEMPO
Semantic	vaso	zapato	BOTELLA

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