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Cognate facilitation effect on verb-based semantic prediction in L2 is modulated by L2 proficiency

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Research Article

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Abstract

We tested whether verb-based prediction in late bilinguals is facilitated when the verb is a cognate versus non-cognate. Spanish–English bilinguals and Chinese–English bilinguals (control) listened to English sentences such as "The girl will adopt the dog" while viewing a scene containing either a dog and unadoptable objects (predictable condition) or a dog and other adoptable animals (unpredictable condition). The verb was either a cognate or non-cognate between Spanish and English and never a cognate between Chinese and English. Both groups of bilinguals were more likely to look at the target (the dog) in the predictable versus unpredictable condition. However, only low-proficient L1 Spanish bilinguals showed greater and earlier prediction when the verb was cognate than when it was non-cognate, suggesting that cognate facilitation effect occurs not only on the cognate word itself but also on prediction based on this cognate word, and that this effect is modulated by L2 proficiency.

Highlights

- Late L2 speakers used verb meaning to predict an upcoming object
- Prediction was facilitated when the verb was a cognate versus a non-cognate
- The cognate facilitation effect occurred only in low-proficient L2 speakers
- Cognate facilitation extends to prediction based on a cognate

1. Introduction

People often predict upcoming language during comprehension (Kuperberg & Jaeger, 2016; Pickering & Gambi, 2018). However, there are large individual differences in prediction, which challenges the view that prediction is ubiquitous (for a discussion, see Huettig & Mani, 2016). For example, second language (L2) speakers do not always predict upcoming language like first language (L1) speakers and their predictions are sometimes slower or less detailed than L1 speakers' (e.g., Hopp, 2015; Ito, Pickering, et al., 2018; Martin et al., 2013; for a review, see Schlenter, 2023). One of the possible accounts for the reduced prediction in L2 is related to co-activation and cross-linguistic influence (Foucart, 2021; Foucart et al., 2014). L2 speakers may activate L1 representations during L2 comprehension (e.g., Spivey & Marian, 1999). When co-activated L1 and L2 representations do not have a one-to-one mapping (e.g., the translation-equivalent words have slightly different meanings), L2 speakers may predict what is predictable based on L1 representations instead of L2 representations. Below, we review evidence for cross-linguistic influence on prediction.

There is evidence that linguistic features that are different between L1 and L2 affect L2 prediction. For example, Van Bergen and Flecken (2017) used visual world eye-tracking and tested prediction based on Dutch placement verbs, which specify different end-state positions: "zetten" ('put'; the placed object is standing), "leggen" ('put'; the placed object is lying) and "plaatsen" ('put'; the end-state position is not specified). German also has similar verbs that specify the end-state position, whereas English and French do not. L1 Dutch speakers and L1 German-L2 Dutch speakers were more likely to look at a standing object over a lying object after hearing "zetten" (and before hearing the object name), but L1 English-L2 Dutch and L1 French-L2 Dutch speakers showed no such predictive eye movements. These findings suggest that L2 speakers are better at using linguistic features that are shared between their L1 and L2 (in this case, the semantic constraints of the verb) for prediction.

Hopp and Lemmerth (2018) tested prediction based on German grammatical gender in L1 German speakers and L1 Russian-L2 German speakers. Both German and Russian have a grammatical gender system and mark gender on suffixes for adjectives. However, they mark gender differently for nouns. German marks gender on prenominal articles and adjectives, whereas Russian marks it on postnominal suffixes. High proficient L1 Russian-L2 German speakers predicted gender-matching referents like L1 German speakers irrespective of where gender was marked (on adjective or article). However, less proficient L1 Russian-L2 German speakers only used gender marking on adjectives for prediction, suggesting that the difference in gender marking between L1 and L2 can influence gender-based prediction in L2. Here, low-proficient L2 German speakers were using only gender marking that was similar in L1 and L2 for prediction.

Alemán Bañón and Martin (2021) used event-related potentials and tested how linguistic features that are realised differently in L1 and L2 affect prediction in L2 using possessives. Like English, Swedish has third-person singular possessive pronouns that mark the possessor's natural gender ("hans" 'his', "hennes" 'her'). In Spanish, possessive pronouns agree with the gender of the possessed noun (e.g., "nuestra madre" 'our$_{\text{-feminine}}$ mother$_{\text{-feminine}}$'), not with the possessor's. Alemán Bañón and Martin created contexts that were predictive toward a possessive construction (e.g., his mother) to test how the above possessive rules affect L1 Swedish and L1 Spanish speakers' prediction in L2 English. L1 English speakers and L1 Swedish-L2 English speakers showed an N400 effect for unexpected (vs. expected) possessive pronouns. However, L1 Spanish-L2 English speakers did not, and instead showed a P600-like effect, suggesting a slower detection of the gender mismatch and/or their qualitatively different predictions from L1 speakers (but see Lago et al., 2023; Stone, Lago, et al., 2021).

Ito et al. (2023) tested prediction based on semantic constraints that were different in two target languages, Vietnamese and German. The Vietnamese verb "mặc" (English 'wear'), for instance, can take a shirt but not earrings as its grammatical object, whereas the German translation equivalent "tragen" can take both. When listening to Vietnamese sentences and presented with a shirt, earrings and other unwearable objects, L1 Vietnamese-L2 German speakers predicted the shirt upon hearing the Vietnamese verb "mặc", as demonstrated by looks to the shirt before it was mentioned. However, German-dominant heritage speakers of Vietnamese were sensitive to the German semantic constraints and distracted by the earrings upon hearing "mặc." A possible explanation for this finding is that co-activation of the nontarget language interferes with prediction when the word used for generating predictions (in this case, "mặc" 'wear') has different constraints in the bilinguals' two languages. Considering that L1 Vietnamese-L2 German did not show sensitivity to the German verb constraints, the interference effect from co-activation may be modulated by proficiency in the nontarget language (in this case, German). In that case, lower proficiency in the L2 seems to be associated with less influence from the L2 semantic constraints for prediction in the L1.

The studies discussed above show instances of how L2 speakers have more difficulties than L1 speakers when the information used to form predictions are different between their languages. Following the same logic, we argue that co-activation of the two languages may facilitate prediction when the word used for generating predictions is a cognate (word sharing form and meaning in two languages) because bilinguals tend to process cognates more efficiently than non-cognates (the *cognate facilitation effect*, e.g., Andras et al., 2022; Blumenfeld & Marian, 2007; Costa et al., 2000; Dijkstra et al., 1999; Muntendam et al., 2022).

For example, Dijkstra et al. (1999) showed that L1 Dutch-L2 English bilinguals recognised cognates faster than non-cognates in a progressive demasking task and a lexical decision task. The cognate facilitation effect was also found in production. Costa et al. (2000) found that L1 Spanish-L2 English bilinguals were faster to name pictures with cognate names than pictures with non-cognate names. Although most early studies tested cognate facilitation in the visual word recognition, several studies found a cognate facilitation effect during auditory word recognition (Andras et al., 2022; Fricke, 2022; Guediche et al., 2020; Muntendam et al., 2022), suggesting that the cognate facilitation effect generalises to the auditory domain (for studies testing the effect of modality on cognate facilitation, see Cornut et al., 2022; Frances et al., 2021). However, it is unclear if the cognate facilitation effect has any downstream consequences beyond the cognate word itself, for prediction at the sentence level for instance, which will be the focus of the present study.

Lauro and Schwartz (2019) tested whether the cognate facilitation effect extends to processing beyond the cognate word itself in an eye-tracking reading study. Spanish–English bilinguals (they learnt Spanish first but were dominant in English) read English (Experiment 1) or Spanish (Experiment 2) sentences with anaphoric references, where an anaphor (e.g., "it", "they") referred to either a cognate (e.g., "sofa", Spanish 'sofá') or non-cognate (e.g., "chairs", 'sillas') noun. They found that not only processing of the cognate but also processing of the anaphor was facilitated by the cognate status of its referent, suggesting that the cognate facilitation can influence processing beyond the cognate word recognition itself. If the cognate facilitation effect occurs not only on retrieval of word meaning but also later on during sentence processing, prediction mechanisms might also differ depending on whether prediction is based on a cognate or non-cognate target word. In that case, we would expect bilinguals to predict quicker and/or to a greater extent when prediction is generated based on a cognate as compared to a non-cognate word.

Regarding modulation of effects based on proficiency, the cognate facilitation effect has been found to depend on L2 proficiency (for a review, see Van Hell & Tanner, 2012). For example, Andras et al. (2022) found a cognate facilitation effect in low proficient (but not highly proficient) bilinguals in a picture selection task where participants listened to either a cognate or non-cognate noun and clicked on the corresponding picture as quickly and accurately as possible. Libben and Titone (2009) found a correlation between L2 proficiency and a cognate facilitation effect during sentence reading, such that the cognate facilitation effect decreased as participants' L2 proficiency increased. Similarly, Bultena et al. (2014) found a reduced cognate facilitation effect during sentence reading for bilinguals with higher L2 proficiency compared to bilinguals with lower L2 proficiency. Interestingly, they also found that the cognate facilitation effect was overall less robust for verbs than for nouns. They speculated that the reduced effect for verbs could be related to syntactic processing required for verbs (e.g., argument structure building) or smaller semantic and word form overlap between languages compared to nouns. Proficiency-modulated cognate facilitation has also been found in production tasks (Blumenfeld et al., 2016).

The cognate facilitation effect and the reduced cognate facilitation effect in more proficient L2 speakers are incorporated into bilingual language processing models such as the revised hierarchical model (Kroll & Stewart, 1994), BIA+ (Dijkstra & van Heuven, 2002), BIA-d (Grainger et al., 2010) and Multilink (Dijkstra et al., 2019). In these models, the cognate facilitation effect is explained by assuming activation from both languages. When Spanish–English bilinguals process cognate words like "piano" (Spanish: 'piano') or "dentist" (Spanish 'dentista'), these words receive activation from both English and Spanish due to the phonological/orthographic similarity. The revised hierarchical model accounts for the proficiency-modulated cognate facilitation effect by assuming that the connection between L1 and L2 words becomes weaker as L2 proficiency increases. BIA-d (which was extended from BIA+) accounts for it by assuming that L1 inhibition from L2 input becomes stronger as L2 proficiency increases. Multilink combines assumptions of the two and can account for it by adjusting the strength of connections between L2 meaning and word form. Although the cognate facilitation effect in word processing has been replicated in various tasks and language groups, confirming the models' assumptions, it is unclear whether it further influences the processing of upcoming language at the sentence level. This will be the focus of our research further developed below.

1.1. Current study and predictions

We tested whether Spanish–English bilinguals' verb-based prediction is facilitated when the verb is a Spanish–English cognate compared to when it is not. To evaluate whether the cognate effect is driven by the cognate status (i.e., not by other lexical difference between cognate and non-cognate verbs), we also tested Chinese–English bilinguals who did not speak Spanish as a control group, as they should be insensitive to the cognate status between Spanish and English. Participants listened to sentences while viewing four objects. One of the objects (target) was predictable or unpredictable based on the main verb of the sentence, which was either a Spanish–English cognate or non-cognate (but never a Chinese–English cognate).

Based on the previous findings on L1 and L2 speakers (Altmann & Kamide, 1999; Dijkgraaf et al., 2017; Ito, Corley, et al., 2018), we expected that participants would be more likely to look at the target object before it is mentioned in the predictable condition than in the unpredictable condition. Critically, if the cognate verb facilitates prediction, we expected that Spanish–English bilinguals, but not Chinese–English bilinguals would predict to a greater extent and/or quicker in the cognate condition than in the non-cognate condition. If the cognate effect was modulated by L2 proficiency, we expected a larger cognate effect on prediction in Spanish–English bilinguals with lower English proficiency compared to those with higher proficiency, based on a reduced influence of the cognate status with increased proficiency (Bultena et al., 2014; Libben & Titone, 2009).

2. Methods

2.1. Participants

Our final sample included 34 L1 Spanish-L2 English late bilinguals (10 males) and 32 L1 Chinese-L2 English late bilinguals (seven males) who had normal or corrected-to-normal vision. The sample size was determined prior to the data collection based on visual world eye-tracking studies that tested L2 speakers and found effects of semantic (verb-mediated) prediction (Chun & Kaan, 2019; Dijkgraaf et al., 2017; Ito, Corley, et al., 2018). None of the L1 Chinese participants had learnt Spanish. We had planned to recruit 32 participants for each group (see preregistration), but we recruited two more L1 Spanish participants because we decided to exclude trials with incorrect translations for this group (see Procedure). An additional four L1 Spanish participants were excluded because they failed to follow the instructions (N = 2) or fixated any of the depicted objects less than 20% of the time in the analysed time window (N = 2). L1 Spanish participants were recruited at BCBL (Basque Center on Cognition, Brain and Language, Spain), and L1 Chinese participants were recruited at the National University of Singapore in Singapore. Table 1 shows the participants' characteristics for each group. L1 Spanish participants had higher LexTALE scores than L1 Chinese participants, $t(64) = -3.1$, $p = .002$. The higher proportion of daily exposure to English in the L1 Chinese group is likely because English is the medium of education and one of the official languages in Singapore, but not in Spain.

Table 1. Participants' characteristics and language backgrounds for the L1 Spanish group and the L1 Chinese group. The *SDs* are in brackets. Participants self-rated their proficiency on a scale from 0 (very low) to 10 (very high) and reported a maximum of four languages they spoke

	L1 Spanish	L1 Chinese
Age (years)	24 (3)	23 (2)
Age of Acquisition: English (years)	6 (2)	6 (2)
Daily exposure to English (%)	14 (10)	39 (19)
Self-rated English: Speaking	7 (2)	7 (2)
Self-rated English: Listening	8 (1)	7 (1)
Self-rated English: Reading	8 (1)	8 (1)
Self-rated English: Writing	7 (1)	7 (1)
LexTALE (English)	75 (12)	65 (10)
Other languages participants spoke: *N* of participants	Basque: 34, French: 16, German: 3, Catalan: 1	Japanese: 5, French: 4, Cantonese: 3, Korean: 3, German: 2, Malay: 1, Thai: 1

2.2. Stimuli

2.2.1. Auditory stimuli

The auditory stimuli comprised 36 critical sentences with an Subject-Object-Verb (SVO) structure, in which the target word was always the sentence-final noun. Each of the critical sentences belonged to one of the two cognate conditions (18 sentences with a cognate verb and 18 sentences with a non-cognate verb). The full list of the sentences is in Appendix. The main verb was a cognate between Spanish and English in the *cognate condition* (e.g., "The girl will adopt the dog.": "adopt" – 'adoptar' in Spanish) and a non-cognate in the *non-cognate condition* (e.g., "The girl will bake the cupcakes.": "bake" – 'hornear' in Spanish). None of the main verbs were cognates between Chinese and English. The word form overlap between Spanish and English was measured using Levenshtein normalised orthographic distance (using RapidFuzz.distance package, Bachmann, 2021) and ALINE phonological distance (using alineR package, Downey et al., 2017). The means are summarised together with other lexical characteristics in Table 2.

The sentences were recorded by a native American English speaker at a slow speech rate (mean sentence duration = 4018 ms, SD = 237). The mean duration from the verb onset to the target word onset was 1536 ms (SD = 177) in the cognate condition and 1514 ms (SD = 107) in the non-cognate condition.

2.2.2. Visual stimuli

Each sentence was paired with a display containing four objects (one target + three distractors). The images for the objects were taken from the ARASAAC pictogram collection (https://arasaac.org/). In the *predictable condition*, the target object was the only plausible object of the verb (e.g., a dog, a sink, a hanger, and a dart

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Table 2. The mean frequency (Zipf-scale), AoA (age of acquisition) and neighbourhood size for cognate verbs and non-cognate verbs in English and Spanish. *SD*s are in parentheses

	Cognate verbs	Non-cognate verbs
Levenshtein normalised orthographic distance	.42 (.16)	.85 (.09)
ALINE phonological distance	.33 (.11)	.66 (.08)
English frequency (SUBTLEX-UK, Van Heuven et al., 2014)	4.32 (.64)	4.73 (.56)
Spanish frequency (EsPal, Duchon et al., 2013)	3.82 (.78)	3.68 (.82)
English AoA (Kuperman et al., 2012)	6.25 (1.79)	5.12 (1.25)
Spanish AoA (Alonso et al., 2015)	5.13 (1.37)	4.76 (1.33)
English neighbourhood size (Marian et al., 2012)	8.28 (9.16)	22.11 (15.37)
Spanish neighbourhood size (EsPal, Duchon et al., 2013)	10.41 (4.57)	12.72 (6.70)

for "adopt", the dog being the target). In the *unpredictable condition*, all four objects were plausible objects of the verb (e.g., a dog, a cat, a hamster and a rabbit for "adopt", the dog being the target). The sentence and the target object were always identical in the predictable and unpredictable conditions within each item, and only one version was presented for each participant (Figure 1).

2.2.3. Plausibility pretest

We assessed the plausibility of each object given the context in a web-based plausibility pretest. We recruited 20 L1 Spanish – L2 English late bilinguals through Prolific (15 males, mean age = 26, age range = 19–39). Their mean English LexTALE score was 81 (range = 56–99). They read the context up to and before the target word (e.g., "The girl will adopt the") together with four objects and rated how plausible each object was to be mentioned after the context using a slider bar with a scale from 0 to 99. The values were not visible to the participants, but the slider bar had "implausible" and "plausible" labels on each side. Participants moved the bar to the right to the extent they thought the object was plausible to be mentioned.

We tested 40 items and excluded four items based on the plausibility ratings. The mean plausibility ratings after the item exclusion are summarised in Table 3. The target was plausible in all conditions, whereas the distractors were implausible in the predictable condition (making the target predictable) and plausible in the unpredictable condition (making the target unpredictable).

2.3. Procedure

Participants listened to the sentences and clicked on the object mentioned in each sentence. Their eye movements were recorded using an EyeLink 1000 Plus Desktop mount eye-tracker sampling at 500 Hz. The eye-tracker was calibrated using the nine-point calibration grid. The pictures were presented on a viewing monitor at a resolution of 1920 × 1080 pixels. Each trial started with a drift check, followed by a 500 ms blank screen, a 3000 ms preview of the scene, and the auditory presentation of the sentence. The scene stayed on the screen for 3000 ms after the offset of the spoken sentence to allow participants some time to click on the target object. No feedback was given throughout the experiment. At the beginning, participants completed two practice trials. The experiment took about 30 minutes. Two experimental lists were constructed, so each participant received the same number of trials per condition, and each sentence was presented only once for each participant (in the predictable or unpredictable condition, counterbalanced across participants). The location of the target was counterbalanced, so that it appeared at each quadrant equally frequently.

L1 Spanish participants completed a translation task after the eye-tracking experiment to ensure that the verb in the cognate condition was a cognate (L1 Chinese participants did not do this test because none of the verbs were Chinese–English cognates). They saw the verb from each item one by one and were asked to translate them into Spanish. If they gave a wrong translation (e.g., translating the verb "knit" to the Spanish verb "llevar," meaning 'wear' in English) or did not know the translation, we excluded the corresponding trials from the eye-tracking data (which affected 3% of the data). If they translated the verb to a synonym of the translation-equivalent we provided in the Appendix (e.g., translating the verb "insert" to "introducer", meaning 'insert' and 'introduce' in Spanish), the translation was considered correct, and we kept the corresponding trial. The exclusion of the items was not included in the preregistration, but we decided to exclude these trials, as the cognate effect should not occur when the translation offered by the participant is wrong. L1 Chinese participants completed the English LexTALE test (Lemhöfer & Broersma, 2012) after the eye-tracking experiment. L1 Spanish participants completed it in another preceding session when they signed up in the participant database of the BCBL (3 years ago on average, range = 0–10 years ago).

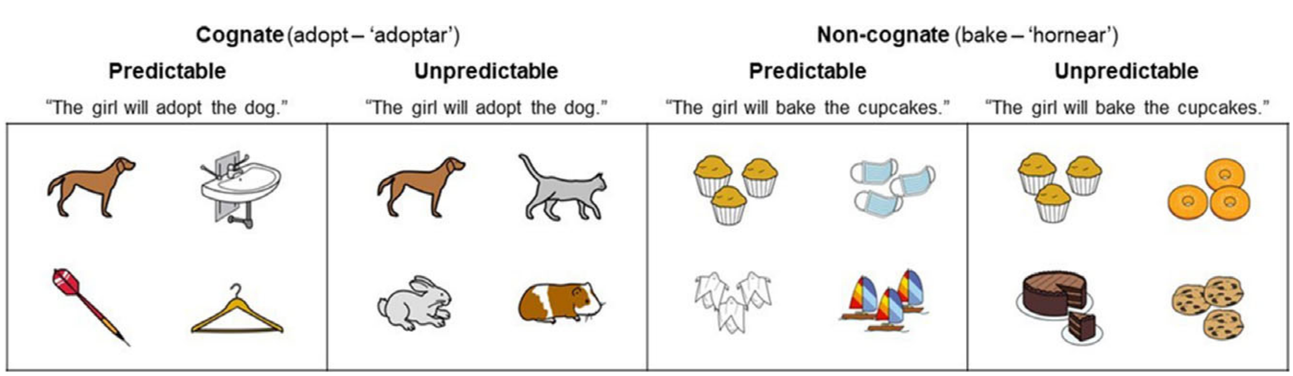

Figure 1. Example of visual stimuli for each condition.

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Table 3. The mean plausibility ratings for each condition and object

Cognate status	Predictability	Object type	Plausibility rating (SD)
Cognate	Predictable	Target	95 (5)
		Distractors	8 (9)
	Unpredictable	Target	88 (9)
		Distractors	84 (11)
Non-cognate	Predictable	Target	94 (4)
		Distractors	4 (6)
	Unpredictable	Target	91 (7)
		Distractors	83 (15)

3. Results

3.1. Comprehension task

The mean accuracy for the task to click the mentioned object was 98% (*SD* = 14) in L1 Spanish speakers and 97% (*SD* = 17) in L1 Chinese speakers.

3.2. Eye-tracking data coding and analysis

We used linear-mixed effects models to test whether the degree of prediction was mediated by the cognate status of the verb. We tested the empirical-logit transformed fixation proportion (Barr, 2008) to the target in the critical time window (from the verb onset +200 ms to the target word onset +200 ms) predicted by main effects of predictability, cognate status and group as well as their full interactions[1]. The 200 ms lag was added to account for the time needed for saccade planning (Saslow, 1967). The categorical variables (predictability, cognate status and group) were sum-coded (predictable = 1, unpredictable = −1; cognate = 1, non-cognate = −1 and L1 Spanish = 1, L1 Chinese = −1). The model initially included the maximal random effects structure justified by the design but was later simplified step-by-step until the model converged without a singular fit. The final model only included by-subject and by-item random intercepts. To test whether the cognate facilitation effect on prediction was modulated by L2 proficiency, we additionally ran a three-way interaction model including main effects of predictability, cognate status and LexTALE score. We ran this model separately for each group because we expected the proficiency-modulated cognate facilitation effect in L1 Spanish speakers but not in L1 Chinese speakers. The LexTALE score was included as a numeric variable and centred.

We additionally used a divergence point analysis (Stone, Lago, et al., 2021) to test how quickly participants started looking at the target. In this analysis, we tested when the fixation proportion to the target in the predictable condition started to diverge from that in the unpredictable condition, and whether this divergence point was different between the cognate versus non-cognate conditions in each group. For this analysis, we computed empirical-logit transformed fixation proportion on the target for every 20 ms time bin relative to the target word onset. A *t*-test testing the effect of predictability on the empirical-logit transformed fixation proportion was run for each time bin to compute a divergence point (the first time bin of 10 consecutive bins that showed a significant effect of predictability in the same direction). Following the recommendations of Stone, Lago, et al. (2021), this was repeated 2000 times to compute the means and credible intervals for each condition and group. This analysis was run in the time window from the mean verb onset +200 ms (= 1320 ms before the target word onset) to the target word onset +1000 ms (the time window was extended in case the divergence occurs after the target word onset). We used Bayes factors to quantify evidence for the alternative versus null hypothesis (Stone, Veríssimo, et al., 2021).

[1]Our preregistered plan was to compute the fixation proportion difference between the predictable and unpredictable conditions and test whether this difference is predicted by main effects and the interaction of cognate status by group. However, we decided against this because the difference can only be computed across different trials. We can still compute the fixation proportion difference for each subject, but we will then lose by-item variability. To model both by-subject and by-item variability in a single model, we ran the three-way interaction model instead.

3.3. Linear mixed-effects models

Figure 2 plots the time-course of the fixation to the target for each condition and group. The analysis testing the interaction of predictability by cognate status by group showed a significant effect of predictability, β = 1.1, *SE* = .06, *t* = 17.6, indicating that participants were more likely to look at the target in the predictable than unpredictable condition. No other main effects or interactions were significant, $|t|s < 2$.

The model that tested the interaction of predictability by cognate status by LexTALE score revealed a significant three-way interaction in the L1 Spanish group, β = −.02, *SE* = .01, *t* = −2.0. This interaction indicates that L1 Spanish speakers with lower English proficiency showed a larger effect of predictability in the cognate (vs. non-cognate) condition, whereas L1 Spanish speakers with higher English proficiency showed a larger effect of predictability in the non-cognate (vs. cognate) condition (Figure 3B). The model additionally found a significant effect of predictability, β = 1.0, *SE* = .12, *t* = 8.5. No other main effects or interactions were significant in the L1 Spanish group. This model included by-subject and by-item random intercepts and a by-subject random slope for predictability.

The same model in the L1 Chinese group found a significant effect of predictability, β = 1.1, *SE* = .09, *t* = 12.6, and a significant effect of LexTALE score, β = .04, *SE* = .01, *t* = 3.2. These effects indicate that L1 Chinese participants predicted the target, and more proficient participants were more likely to look at the target overall. No other main effect or interactions were significant in the L1 Chinese group. This model included by-subject and by-item random intercepts and a by-item random slope for cognate status.

3.4. Divergence point analysis

The divergence point analysis revealed that the estimated divergence point relative to the target word onset was −869 ms, 95% CI = [−920, −800] in the cognate condition and −721 ms, 95% CI = [−820, −560] in the non-cognate condition in the L1 Spanish group and the divergence point was similar in the cognate and non-cognate conditions (Bayes factor = .07). In the L1 Chinese group, the divergence point was also similar in the cognate condition (*M* = −897 ms, 95% CI = [−980, −820]) and in the non-cognate condition (*M* = −858 ms, 95% CI = [−940, −720]) (Bayes factor = .07).

To test the effect of participants' English proficiency, we divided participants in each language group into high- and low-proficiency groups via a median-split of their LexTALE score (Figure 3A). In the L1 Spanish high proficiency group, the mean divergence point

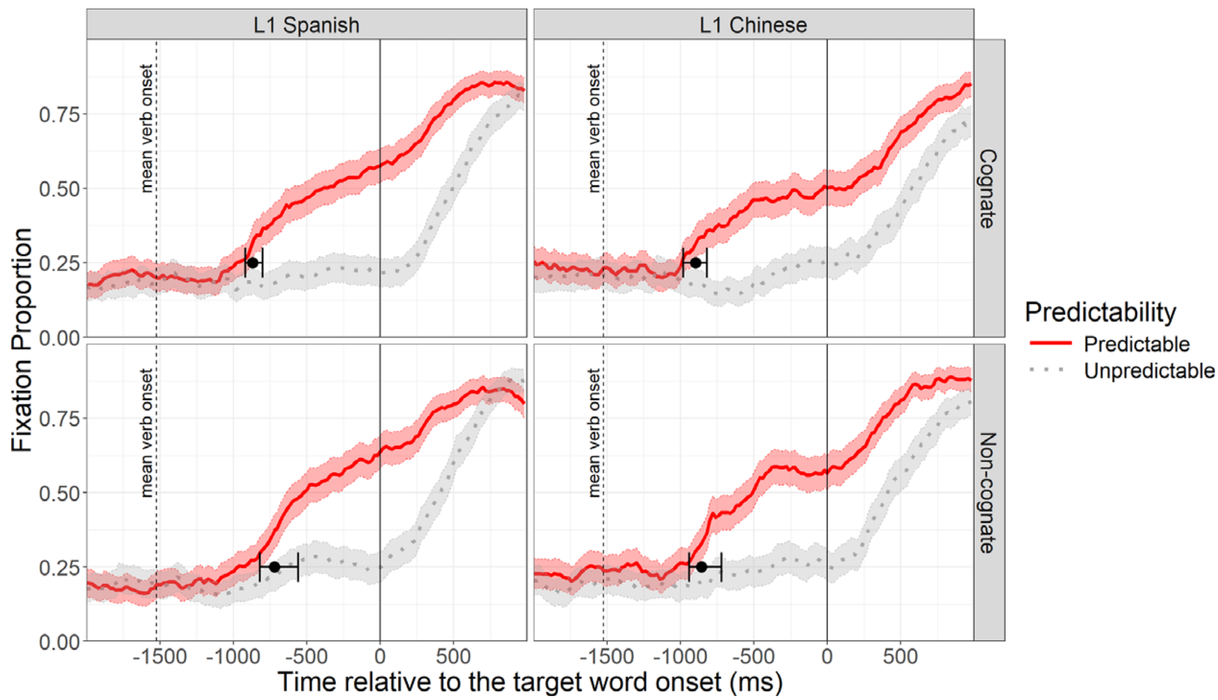

Figure 2. The target fixation proportion averaged for each 20 ms time bin relative to the target word onset in the cognate condition (top) and non-cognate condition (bottom), in the L1 Spanish group (left) and the L1 Chinese group (right). The transparent thick lines around the mean are error bars representing 95% confidence intervals. The black dot in each plot is the divergence point between the predictable and unpredictable conditions with 95% credible intervals.

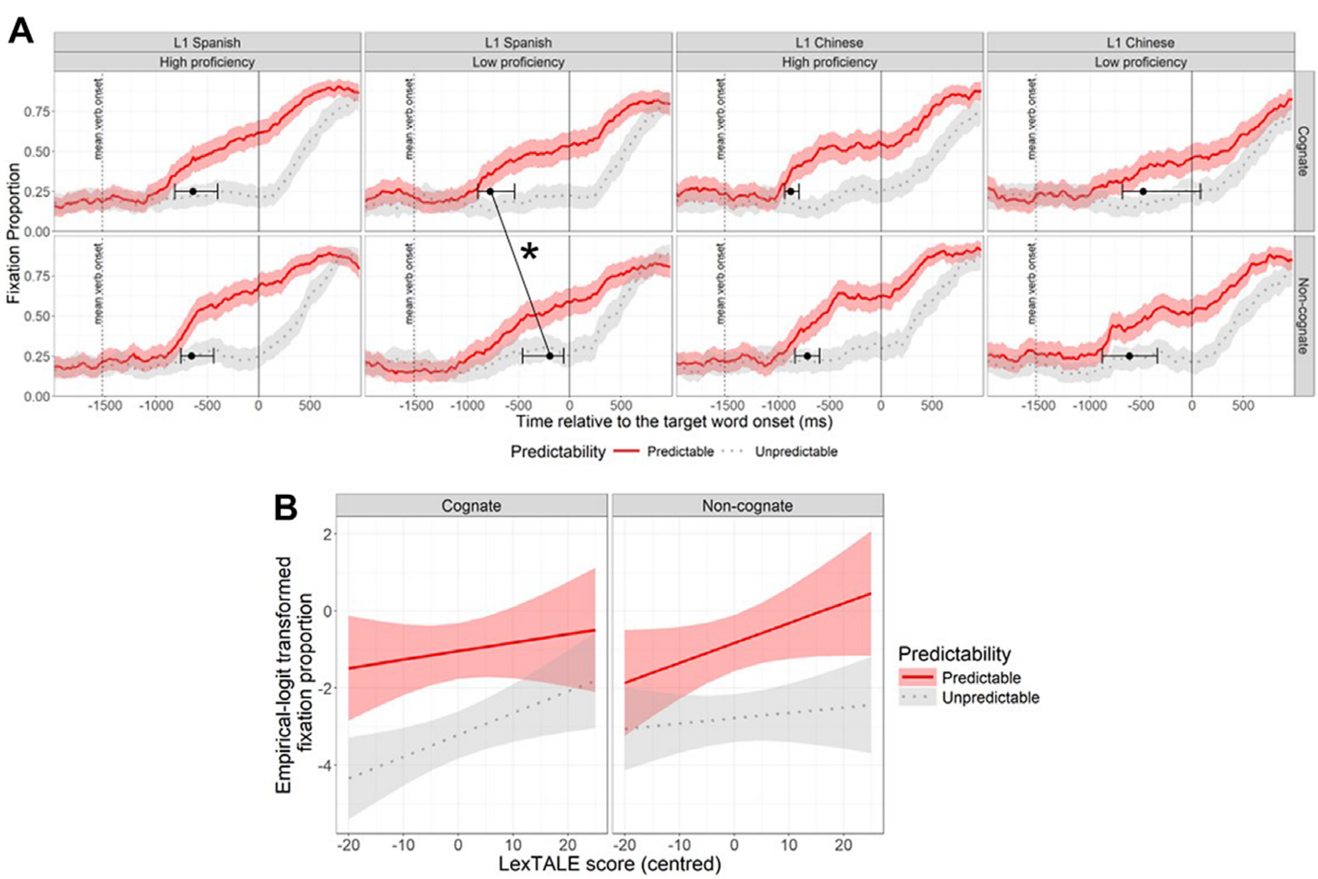

Figure 3. Effects of proficiency (LexTALE). (A) The target fixation proportion averaged for each 20 ms time bin relative to the target word onset in the cognate condition (top) and non-cognate condition (bottom) and in the high proficiency group (left) and low proficiency group (right) within each group (L1 Spanish, L1 Chinese). The transparent thick lines around the mean are error bars representing 95% confidence intervals. The black dot in each plot is the divergence point between the predictable and unpredictable conditions with 95% credible intervals. (B) Estimated marginal means with 95% confidence intervals from the linear mixed-effects model testing the interaction of predictability, cognate status and (centred) LexTALE score in the L1 Spanish group.

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relative to the target word onset was −644 ms, 95% CI = [−820, −400] in the cognate condition and −658 ms, 95% CI = [−760, −440] in the non-cognate condition (Bayes factor = .01; i.e., the data are 100 times more likely under the null hypothesis). In the L1 Spanish low-proficiency group, the mean divergence point was −780 ms, 95% CI = [−900, −540] in the cognate condition and −196 ms, 95% CI = [−460, −60] in the non-cognate condition (Bayes factor = 269.3; the data are 269 times more likely under the alternative hypothesis). The low-proficiency group predicted the target more slowly than the high-proficiency group in the non-cognate condition, suggesting the role of L2 proficiency in L2 prediction. Interestingly, the low-proficiency group predicted the target similarly quickly as the high-proficiency group in the cognate condition, suggesting that the low-proficiency group benefitted from the cognate status of the verb to a larger extent than the high-proficiency group.

In the L1 Chinese high-proficiency group, the mean divergence point was −882 ms, 95% CI = [−940, −800] in the cognate condition and −720 ms, 95% CI = [−840, −600] in the non-cognate condition (Bayes factor = .09). In the L1 Chinese low-proficiency group, the mean divergence point was −480 ms, 95% CI = [−600, 80] in the cognate condition and −614 ms, 95% CI = [−880, −340] in the non-cognate condition (Bayes factor = .03). As expected, prediction in the L1 Chinese group was unaffected by the cognate status of the verb, regardless of their English proficiency. In sum, only the L1 Spanish low-proficiency group showed an earlier divergence point in the cognate versus non-cognate condition, indicating that they were quicker to predict the target based on a cognate verb than a non-cognate verb.

4. Discussion

On a group-level, L1 Spanish-L2 English speakers and L1 Chinese-L2 English speakers showed similar effects of predictability, both in terms of the size and speed of the prediction effect. These effects occurred prior to the target word onset, suggesting that L2 speakers can use verb semantic constraints for prediction, in line with previous findings (e.g., Chambers & Cooke, 2009; Dijkgraaf et al., 2017, 2019; Ito, Corley, et al., 2018). Our goal was to test whether this verb-based prediction effect is greater or occurs earlier when the verb is a cognate compared to when it is not. We expected to find this interaction in the L1 Spanish group but not in the L1 Chinese control group because we manipulated the cognate status between Spanish and English. Overall, we did not find a three-way interaction of predictability by cognate status by group. The divergence point analysis also found similarly early prediction in the cognate and non-cognate conditions in the two groups.

However, as discussed in the introduction, previous studies suggest that the cognate facilitation effect is modulated by proficiency (Andras et al., 2022; Bultena et al., 2014; Libben & Titone, 2009; Van Hell & Tanner, 2012). Consistent with these studies, we found a three-way interaction of predictability by cognate status by English proficiency in the L1 Spanish group, indicating that participants whose English proficiency was lower showed a greater predictability effect when the verb was a cognate compared to when it was a non-cognate. The predictability effect did not interact with the cognate status or proficiency in the L1 Chinese group, suggesting that the interaction in the L1 Spanish group is unlikely to be driven by any features of the stimuli. These findings are corroborated by the results of the divergence point analysis, which revealed that L1 Spanish speakers with lower English proficiency were quicker to predict the target referent in the cognate versus non-cognate condition, whereas L1 Spanish speakers with higher English proficiency or L1 Chinese speakers (irrespective of English proficiency) showed no effect of cognate status.

4.1. Cognate facilitation effect beyond a cognate word

Our findings suggest that the cognate facilitation effect has a downstream effect on subsequent predictive processing. This is in line with the finding that anaphoric reference processing can be facilitated by the cognate status of the anaphor referent (Lauro & Schwartz, 2019), which also suggests that the cognate facilitation effect can influence processing beyond the recognition of a cognate word. Although our study differed from their study in several respects including participants' English proficiency and the linear distance between the target word and the cognate word, we believe their study helps explaining our findings. Lauro and Schwartz preliminarily proposed that the cognate facilitation effect on anaphor processing could be because the stronger activation of a cognate word (which receives activation from two languages) allows its representation in the memory trace to be more readily accessible during the comprehension of anaphor references. When Spanish–English bilinguals comprehend sentences, such as "The sofa was next to the chairs that were made of wood, but it was…" (where "sofa" but not "chairs" was a cognate between Spanish and English), the sofa may be activated more strongly than the chairs because of its cognate status. When they reach the anaphor "it", they need to access the correct referent from their memory. This referent search may become easier when the correct referent was more strongly activated.

The stronger activation for cognate than non-cognate words can explain our results. It is possible that Spanish–English bilinguals with lower English proficiency in our study activated cognate verbs more strongly than non-cognate verbs. Then, it could be that they were engaged in deeper semantic processing of the cognate verbs and hence were more efficient in using the semantic constraints of the cognate verbs for prediction. An alternative possibility is that they retrieved the meaning of cognate (vs. non-cognate) verbs more quickly, and this freed up some time or cognitive resources that could be used for other processes like prediction. Considering the prior findings that generating prediction requires time and resources (Huettig & Guerra, 2019; Huettig & Janse, 2016; Ito, Corley, et al., 2018; Ito, Pickering, et al., 2018; Li & Qu, 2023), the availability of the extra time or resources due to quicker processing of cognates (vs. non-cognates) may have facilitated prediction.

4.2. Theoretical implications for prediction in L2

In our study, we found both groups of L2 speakers used verb meaning for prediction, and the prediction effect was evident in relatively low proficient speakers too, replicating previous findings (Chambers & Cooke, 2009; Dijkgraaf et al., 2017, 2019; Ito, Corley, et al., 2018). However, previous work on L2 prediction has found that prediction in L2 can be reduced or delayed (Hopp, 2015; Ito, Pickering, et al., 2018; Martin et al., 2013). Among the possible accounts for reduced prediction in L2 versus L1, cross-linguistic influence has been proposed to affect bilinguals' prediction (e.g., Foucart, 2021; Kaan, 2014). Evidence supporting this account comes from studies showing that L2 speakers have difficulty using linguistic cues that do not exist in their L1 (Hopp, 2015; Van Bergen & Flecken, 2017) or cues that do not have a one-to-one mapping between their L1 and L2 (Hopp & Lemmerth, 2018; Ito et al., 2023) to build predictions in their L2. However, the proposal for the cross-linguistic influence implies both inhibitory and facilitatory effects. Thus, it follows that prediction may be facilitated when the linguistic cues used for generating predictions have similar representations in L1 and L2 (e.g., cognates). Previous studies have also found that the cross-linguistic influence on L2 prediction is smaller as L2 proficiency increases (Hopp, 2013; Hopp & Lemmerth, 2018). Consistent with these studies, we found that the cognate facilitation effect on prediction was modulated by L2 proficiency, such that L2 speakers with lower proficiency were particularly subject to cross-linguistic influence. This can explain reduced prediction in L2 when prediction can be generated based on L2 cues that do not have similar representations in L1. Crucially, we found that it can also facilitate L2 prediction when prediction can be generated based on a cognate, which shares word form and meaning representations in L1 and L2.

4.3. Theoretical implications for bilingual lexical access

Our study found a cognate facilitation effect on prediction based on verbs, where the verbs were either cognate or non-cognate. This is interesting as previous studies investigated the cognate facilitation effect predominantly using noun cognates (e.g., faster reading times for cognate nouns vs. non-cognate nouns), and as the cognate facilitation effect seems stronger for nouns than for verbs (Bultena et al., 2014). Van Assche et al. (2013) found the cognate facilitation effect using verbs in lexical decision and eye-tracking reading experiments, but the effect on eye-tracking reading measures was only found in a late measure (go-past time). This late effect was at odds with previous studies where the noun cognate facilitation effect was found on early measures such as gaze duration and skipping rates (e.g., Libben & Titone, 2009; Van Assche et al., 2011). Van Assche et al. (2013) suspected that the late effect for cognate verbs could be because cognate verbs tend to have less between-language orthographic overlap than cognate nouns. They also suggested that sentence contexts provided clear language cues, and this may have weakened cross-linguistic activation. This possibility is consistent with previous studies showing that a constraining sentence context weakens cross-linguistic activation (Chambers & Cooke, 2009; Libben & Titone, 2009).

In our study, the critical verbs were always preceded by a clear language cue (e.g., "The girl will…" signalling that the continuation is likely to be English). This cue may limit cross-linguistic activation at the verb, but it did not eliminate the cognate facilitation effect. In fact, this finding is consistent with existing evidence for cross-linguistic activation in low-constraining contexts even when there was a clear language cue (Lauro & Schwartz, 2017). Interestingly, Van Assche et al. (2013) suggested that another possible explanation for the late effect they found could be related to the easier semantic processing or integration for cognates versus non-cognates. If the cognate facilitation effect for verbs comes from the eased semantic processing, this seems to offer a straightforward explanation for the cognate facilitation effect on verb meaning-based prediction in our study.

Overall, the cognate facilitation effect modulated by L2 proficiency in our study supports proficiency-dependent nonselective lexical access as predicted in models such as BIA-d (Grainger et al., 2010), the revised hierarchical model (Kroll & Stewart, 1994) and Multilink (Dijkstra et al., 2019). We found no evidence for a cognate facilitation effect in more proficient L2 speakers, suggesting that cognate status does not uniformly benefit L2 speakers. A possible explanation for the lack of the cognate facilitation effect in more proficient L2 speakers is that they have richer and more detailed lexical representations of L2 than less proficient L2 speakers, and they may benefit from the form similarity to a lesser extent because they rely less on L1 representations during L2 processing.

Another somewhat related possibility is that the lexical representations of more proficient L2 speakers include small meaning differences between the L1 and L2 translation equivalents. This may affect the processing of cognates when the cognates have multiple meanings in one of the languages because more proficient L2 speakers but not less proficient L2 speakers may activate multiple meanings. Indeed, prior work has shown that subordinate meanings of homonyms that were cognates with L1 ('weapon' meaning of "arm"; 'arma' in Spanish only has the 'weapon' meaning) were more readily accessible than non-cognate subordinate meanings during L2 processing (Arêas da Luz Fontes & Schwartz, 2010, 2015). Other work suggests that this L1 influence on homonym processing is greater in less proficient L2 speakers (Elston-Güttler et al., 2005). In our study, more proficient L2 speakers may have co-activated the L2 verb meaning that is not in the L1 translation equivalent (e.g., "move" in English but not 'mover' in Spanish can refer to changing residence), reducing the benefit from form overlap.

5. Conclusion

Our study shows that the well-replicated cognate facilitation effect extends to prediction based on a cognate verb. Although many studies have found that cognates are processed faster than non-cognates, and that this effect is modulated by proficiency, our study is one of the few studies that showed that the proficiency-modulated cognate facilitation effect extends to processing beyond the cognate word itself. This has implications for research investigating language processing in bilinguals; researchers need to carefully control for cognate status of not only critical words but also words that precede them because a facilitation effect on the critical words may come partially from preceding cognate words. Additionally, given that low proficient L2 speakers rely more on cognate verbs than non-cognate verbs for prediction, facilitating downstream processing, teaching cognate words before non-cognate words may be beneficial for L2 learners before they reach a certain level of proficiency.

Data availability statement. The preregistration (https://osf.io/7zj8y), the data and the analysis scripts (https://osf.io/h2vg7/) are publicly available.

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Appendix

Critical sentences and object names for each condition. Spanish and Chinese translations of the main verb. Pinyin and tone are provided for the Chinese translations.

Item	Predictability	Cognate status	Sentence	Target	Verb in Spanish	Verb in Chinese	Distractors
1	Predictable	Cognate	The girl will adopt the dog.	dog	Adoptar	领养 /ling3yang3 /	sink, hanger, dart
1	Unpredictable	Cognate	The girl will adopt the dog.	dog	Adoptar	领养 /ling3yang3 /	cat, hamster, rabbit
2	Predictable	Cognate	The boy will collect the stamps.	stamps	Coleccionar	收集 /shou1ji2/	roads, towers, waves
2	Unpredictable	Cognate	The boy will collect the stamps.	stamps	Coleccionar	收集 /shou1ji2/	marbles, postcards, photographs
3	Predictable	Cognate	The lady will count the tables.	tables	Contar	数 /shu3/	sun, moon, waterfall
3	Unpredictable	Cognate	The lady will count the tables.	tables	Contar	数 /shu3/	sheep, medals, caps
4	Predictable	Cognate	The man will cut the tomato.	tomato	Cortar	切 /qie1/	ring, umbrella, brick
4	Unpredictable	Cognate	The man will cut the tomato.	tomato	Cortar	切 /qie1/	rope, paper, watermelon
5	Predictable	Cognate	The girl will decorate the album.	album	Decorar	装饰 /zhuang1shi4/	starfish, spoon, iceberg
5	Unpredictable	Cognate	The girl will decorate the album.	album	Decorar	装饰 /zhuang1shi4/	notebook, frame, locker
6	Predictable	Cognate	The woman will donate the clothes.	clothes	Donar	捐/捐赠 /juan1/ /juan1zeng4/	balcony, stairs, park
6	Unpredictable	Cognate	The woman will donate the clothes.	clothes	Donar	捐/捐赠 /juan1/ /juan1zeng4/	toys, books, shoes
7	Predictable	Cognate	The lady will move the mouse.	(computer) mouse	Mover	移动 /yi2dong4/	fire, earth, rainbow
7	Unpredictable	Cognate	The lady will move the mouse.	(computer) mouse	Mover	移动 /yi2dong4/	cage, sofa, laptop
8	Predictable	Cognate	The woman will fry the egg.	egg	Freír	煎 /jian1/	suitcase, water bottle, plane
8	Unpredictable	Cognate	The woman will fry the egg.	egg	Freír	煎 /jian1/	potato, bacon, steak
9	Predictable	Cognate	The man will inflate the balloon.	balloon	Inflar	吹 /chui1/	leaf, camera, telescope
9	Unpredictable	Cognate	The man will inflate the balloon.	balloon	Inflar	吹 /chui1/	wheel, rubber ring, ball
10	Predictable	Cognate	The boy will insert the coin.	coin	Insertar	投 /tou2/	glove, trumpet, curtain
10	Unpredictable	Cognate	The boy will insert the coin.	coin	Insertar	投 /tou2/	pen drive, key, credit card
11	Predictable	Cognate	The man will invite the girl.	girl	Invitar	邀请 /yao1qing3/	rolling pin, horse, mug
11	Unpredictable	Cognate	The man will invite the girl.	girl	Invitar	邀请 /yao1qing3/	boy, couple, family
12	Predictable	Cognate	The woman will paint the nail.	nail	Pintar	涂 /tu2/	swan, snake, milk
12	Unpredictable	Cognate	The woman will paint the nail.	nail	Pintar	涂 /tu2/	drawing, fence, wall

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(*Continued*)

Item	Predictability	Cognate status	Sentence	Target	Verb in Spanish	Verb in Chinese	Distractors
13	Predictable	Cognate	The man will plant the tree.	tree	Plantar	种 /zhong3/	bowl, cow, kite
13	Unpredictable	Cognate	The man will plant the tree.	tree	Plantar	种 /zhong3/	tulip, cactus, palm tree
14	Predictable	Cognate	The lady will prepare the salad.	salad	Preparar	准备 /zhun3bei4/	mirror, mermaid, shark
14	Unpredictable	Cognate	The lady will prepare the salad.	salad	Preparar	准备 /zhun3bei4/	lasagna, tea, pancakes
15	Predictable	Cognate	The man will print the document.	document	Imprimir	打印 /da3yin4/	bin, tiger, alarm clock
15	Unpredictable	Cognate	The man will print the document.	document	Imprimir	打印 /da3yin4/	recipe, list, plan
16	Predictable	Cognate	The child will receive the present.	present	Recibir	收到 /shou1dao4/	planet, church, pool
16	Unpredictable	Cognate	The child will receive the present.	present	Recibir	收到 /shou1dao4/	mail, money, message
17	Predictable	Cognate	The man will toast the bread.	bread	Tostar	烤 /kao3/	lion, button, lime
17	Unpredictable	Cognate	The man will toast the bread.	bread	Tostar	烤 /kao3/	bagel, croissant, sandwich
18	Predictable	Cognate	The man will use the scissors.	scissors	Usar	用 /yong4/	jellyfish, castle, fireworks
18	Unpredictable	Cognate	The man will use the scissors.	scissors	Usar	用 /yong4/	screwdriver, shovel, hammer
19	Predictable	Non-cognate	The girl will bake the cupcakes.	cupcakes	Hornear	烤 /kao3/	masks, boats, ghosts
19	Unpredictable	Non-cognate	The girl will bake the cupcakes.	cupcakes	Hornear	烤 /kao3/	donuts, cookies, chocolate cake
20	Predictable	Non-cognate	The boy will bite the apple.	apple	Morder	咬 /yao3/	cup, crane, bridge
20	Unpredictable	Non-cognate	The boy will bite the apple.	apple	Morder	咬 /yao3/	pear, biscuit, hot dog
21	Predictable	Non-cognate	The lady will burn the candle.	candle	Quemar	点燃 /dian3ran2/	rain, snowflake, river
21	Unpredictable	Non-cognate	The lady will burn the candle.	candle	Quemar	点燃 /dian3ran2/	incense, chicken, wood
22	Predictable	Non-cognate	The man will chase the mouse.	(animal) mouse	Perseguir	抓 /zhua1/	lamp, olive, boot
22	Unpredictable	Non-cognate	The man will chase the mouse.	(animal) mouse	Perseguir	抓 /zhua1/	tennis ball, lizard, deer
23	Predictable	Non-cognate	The girl will close the window.	window	Cerrar	关 /guan1/	chair, wheat, magnet
23	Unpredictable	Non-cognate	The girl will close the window.	window	Cerrar	关 /guan1/	folder, fridge, box
24	Predictable	Non-cognate	The woman will hear the bell.	bell	Escuchar	听到 /ting1dao4/	clover, rubber, knife
24	Unpredictable	Non-cognate	The woman will hear the bell.	bell	Escuchar	听到 /ting1dao4/	bird, alarm, train
25	Predictable	Non-cognate	The lady will iron the shirt.	shirt	Planchar	熨 /yun4/	watch, avocado, snail
25	Unpredictable	Non-cognate	The lady will iron the shirt.	shirt	Planchar	熨 /yun4/	skirt, handkerchief, tie
26	Predictable	Non-cognate	The woman will knit the sweater.	sweater	Tejer	织 /zhi1/	tray, banana, ant

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(*Continued*)

Item	Predictability	Cognate status	Sentence	Target	Verb in Spanish	Verb in Chinese	Distractors
26	Unpredictable	Non-cognate	The woman will knit the sweater.	sweater	Tejer	织 /zhi1/	scarf, blanket, hat
27	Predictable	Non-cognate	The man will melt the chocolate.	chocolate	Derretir	融化 /rong2hua4/	broom, dolphin, mushroom
27	Unpredictable	Non-cognate	The man will melt the chocolate.	chocolate	Derretir	融化 /rong2hua4/	cheese, ice, butter
28	Predictable	Non-cognate	The boy will open the door.	door	Abrir	打开/开 /da3kai1/ /kai1/	brush, lettuce, harp
28	Unpredictable	Non-cognate	The boy will open the door.	door	Abrir	打开/开 /da3kai1/ /kai1/	backpack, lock, drawer
29	Predictable	Non-cognate	The man will play the guitar.	guitar	Tocar	弹 /tan2/	stapler, kiwi, diamond
29	Unpredictable	Non-cognate	The man will play the guitar.	guitar	Tocar	弹 /tan2/	violin, piano, flute
30	Predictable	Non-cognate	The woman will read the book.	book	Leer	看/读 /kan4/ /du2/	cart, pizza, onion
30	Unpredictable	Non-cognate	The woman will read the book.	book	Leer	看/读 /kan4/ /du2/	newspaper, letter, magazine
31	Predictable	Non-cognate	The man will sell the carrots.	carrots	Vender	卖 /mai4/	clouds, mountains, stars
31	Unpredictable	Non-cognate	The man will sell the carrots.	carrots	Vender	卖 /mai4/	pens, toilet paper, eggs
32	Predictable	Non-cognate	The lady will smell the flower.	flower	Oler	闻 /wen2/	stool, CD, swing
32	Unpredictable	Non-cognate	The lady will smell the flower.	flower	Oler	闻 /wen2/	fish, perfume, popcorn
33	Predictable	Non-cognate	The man will spread the peanut butter.	peanut butter	Untar	抹/涂 /mo3/ /tu2/	torch, spider, racket
33	Unpredictable	Non-cognate	The man will spread the peanut butter.	peanut butter	Untar	抹/涂 /mo3/ /tu2/	chocolate spread, honey, cream cheese
34	Predictable	Non-cognate	The man will squeeze the lemon.	lemon	Exprimir	挤 /ji3/	battery, anchor, TV
34	Unpredictable	Non-cognate	The man will squeeze the lemon.	lemon	Exprimir	挤 /ji3/	toothpaste, orange, grapes
35	Predictable	Non-cognate	The man will taste the wines.	wines	Probar	尝尝/尝一尝 /chang2chang/ /chang2yi4chang2/	traffic signs, whistles, bikes
35	Unpredictable	Non-cognate	The man will taste the wines.	wines	Probar	尝尝/尝一尝 /chang2chang/ /chang2yi4chang2/	blueberries, soups, ice creams
36	Predictable	Non-cognate	The man will wash the dish.	dish	Lavar	洗 /xi3/	microscope, butterfly, paper plane
36	Unpredictable	Non-cognate	The man will wash the dish.	dish	Lavar	洗 /xi3/	fork, sock, car

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