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Cross-language Sense Priming

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CROSS-LANGUAGE SENSE

PRIMING

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Abstract

Research has yet to systematically examine the extent to which activation spreads across multiple senses of words. The two present experiments focused on examining the effects of cross-language sense priming via processing polysemous words in and out of a sentence context. In Experiment 1, participants made semantic verification of word pairs; critical trials contained polysemous words. In Experiment 2, participants read sentences in an eye-tracker with critical sentences containing both instantiations of a polysemous word. Results from both experiments suggested that senses can be primed within and across languages. These results give support for the DFM's interconnective network of conceptual features. Additionally, cognate status created competition restricting spread of activation, which gives support for the DFM's interconnective network of lexical features. Also, sense status modulated priming such that activation spread more strongly across shared senses, but evidence for this was very limited. These results suggest that the DFM's network is less graded than originally thought, and conceptual features that are not used in one language become linked to both lexical forms.

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Chapter 1: Introduction

A remarkable aspect of language use is the ease with which we infer the correct meaning of words that we hear or read, despite the fact that there is rarely a simple one-to-one mapping between a word and its meaning. Many words in any given language have multiple senses. For example, ring can refer to a piece of jewelry or a place where a boxing match takes place. Research with monolinguals demonstrates these multiple senses are activated in parallel (e.g., Rodd, Gaskell, Marlsen-Wilson, 2002; Klepousniotou, 2002). Mappings between word forms and meanings are even more complex for bilinguals. First for any given concept, a bilingual has at least two potential ways of naming it. Second, translations of words across languages are rarely equivalent since many words have different senses across languages. For example, the Spanish translation of *ring*, *anillo* does not include the boxing ring sense. The goal of the present study was to examine whether multiple senses of words are activated in parallel across languages in ways similar to what has been observed within a single language with monolinguals. We also examined whether cross-language activation is restricted to only senses that are shared across languages or extends to even those that are unique to just one language. Finally, we also examined if the extent of activation is further modulated by overlap in word form across languages by comparing processing of cognates and noncognates.

THE DISTRIBUTED FEATURES MODEL

Substantial research has been dedicated to understanding the cognitive architecture that connects word forms across languages to their underlying concepts and how these concepts are activated and retrieved via word forms across the two languages (Kroll & Stewart, 1994; van Hell & de Groot, 1998; Dijkstra & Van Heuven, 2002). There is consensus in the literature that words forms across languages are connected to a single, conceptual store. In this way translations are linked to an integrated conceptual representation. However, since words can take on different senses across languages, conceptual overlap is not always complete. The distributed features model (DFM) (van Hell & de Groot, 1998) of bilingual conceptual-lexical memory assumes that words are comprised of a distribution of lexical and conceptual features within an interconnected network. As such, the degree of cross-language overlap in form and meaning is a matter of degree. This architecture allows the model to account for differences in the degree of overlap between translations in terms of lexical form and meaning. For example, the Spanish-English cognates, *firm/firme* and *goal/gol*, would both have extensive overlap in lexical form and conceptual features. However, the overlap in conceptual features would be less extensive for *goal/gol* because it has a sense in English that does not exist in Spanish (something someone wants to achieve), whereas both senses of firm exist in both languages. Similar distinctions exist amongst noncognates such as *earth/tierra* and *ring/anillo*. For these translations the overlap is exclusively amongst conceptual features, and the extent of the overlap is greater for earth/tierra since both senses of the word exist across both languages. These graded differences in overlap are captured by the model through varying strength of connections amongst the various features (see Figure 1). Those that are not shared across languages have weaker connections and are therefore receive less activation during retrieval.

In one study that tested the architectural assumptions of the DFM highly-proficient Spanish-Catalan bilinguals performed a translation recognition task for words that either had a single or multiple translations in the target language (Boada, Sánchez-Casas, Gavilán, Garcia-Albea, & Tokowicz, 2013). Overall, performance was superior for words with a single translation, suggesting that the complete overlap in features allowed those features to be more strongly connected in the network. Also, amongst words with multiple translations, performance was better for dominant (higher frequency) translations than subordinate translations.

Although the study by Boada and others (2013) provides evidence supporting some of the key assumptions of the DFM, critical questions remain. First, it should be noted that if it is true that the various lexical form and conceptual features of translations exist within a fully interconnected network through which activation spreads, then features that are unique to one language should become increasingly connected to word form features in the alternative language. This assumption of the model, to the best of our knowledge, has not been directly tested. Second, it is unknown if there is similar activation of features across languages when the task does not involve explicit translation.

Most studies supporting current models of bilingual conceptual-lexical memory such as the DFM have been based on translation tasks. It is unknown how the dynamics of activation may differ during pure comprehension tasks. This is a critical gap in literature since it has been clearly demonstrated that words from a bilingual's two languages become activated during comprehension. This research is reviewed next.

CROSS-LANGUAGE ACTIVATION OF LEXICAL FORM AND MEANING

Numerous studies have found that when bilinguals access a word in one language, activation flows to lexical representations across both languages (e.g., Dijkstra, 2005; Grainger, 1993; Dijkstra, Van Jaarsveld, & Ten Brinke, 1998; Costa, Caramazza, & Sebastian-Galles, 2000; Duyck, Van Assche, Drieghe, & Hartsuiker, 2007; Libben & Titone, 2009; Schwartz & Kroll, 2006). The most robust and consistent finding has been that of cognate facilitation. Cognates are identified faster and more accurately than matched controls across a variety of word recognition tasks such as lexical decision and naming (Dijkstra et al., 1998; Costa et al., 2000). Cognate facilitation effects are assumed to emerge because there are two sources of evidence within the lexicon that are co-activated and the overlap in form and meanings facilitates access. Later studies examine if this effect persists in sentence context, and a similar conclusion was reached. Co-activation persists and the strength/timing of activation is modulated by contextual bias (Duyck et al., 2007; Libben & Titone, 2009; Schwartz & Kroll, 2006).

The Bilingual Interactive Activation Plus model (BIA+) is a model of bilingual word recognition that assumes there is an integrated lexicon through which activation spreads across both languages (Dijkstra & Van Heuven, 2002). Presentation of a letter string causes activation of lexical representations that match the string across languages. The key determinant of the level of activation a representation receives depends on the extent to which it matches the input, regardless of language membership. Cognate facilitation effects are assumed to be due to the greater degree of bottom-up activation from orthography to semantics, which also produces strong top-down, resonant activation from semantics back to orthography, speeding lexical retrieval. Cognate facilitation effects can be reduced, eliminated or even reversed into interference, when there is less overlap in orthographic form and/or semantics. This is because co-activated orthographic and semantic units will compete and slow retrieval.

Most research demonstrating effects of cross-language activation has focused on the processing of cognates and interlingual homographs that have one meaning in each language and are therefore unambiguous within a language. Only a few studies have examined whether cross-language activation spreads to word meanings that exist in only one of the bilingual's languages and also whether activation spreads in the absence of overlapping form (Elston-Güttler, Paulmann, & Kotz, 2005; Elston-Güttler & Friederici, 2005).

In one study German-English bilinguals were presented with all L2 (English) sentences followed by target words for which participants made a lexical decision (Elston-Güttler et al., 2005). On critical trials, the sentences ended in a prime word whose German translation was a homonym (e.g., pine in German is Keifer, which also means jaw), and the follow-up target word was related to the German-specific meaning. Decision latencies were slower for targets related to the German-specific meaning relative to controls, but only for less proficient bilinguals (Elston-Güttler et al., 2005). This pattern indicates that cross-language activation spread to word meanings that exist in only one of the bilingual's languages and even for words that do not have any word form overlap across languages.

Across a series of studies Schwartz and colleagues have examined bilingual processing of within-language homographs for which one meaning is shared (e.g., novel/novela, share the "book" meaning, but the "new" meaning only exists in English) (e.g., Arêas da Luz Fontes & Schwartz, 2011; 2014; Schwartz, Yeh & Shaw, 2008). Their findings converge in demonstrating that cognate meanings of within language homographs are more strongly activated than meanings of homographs that are not cognates. For example, in one study highly-proficient Spanish-English bilinguals read all-English sentences that ended in a homograph that was either a cognate sharing the dominant meaning (*novel/novela*) or a non-cognate (Schwartz et al., 2008). After each sentence they decided whether a follow-up target word was related to the meaning of the sentence they had just read. On critical trials, the sentence biased the less-frequent meaning of the homograph (e.g., "She was creative, and her ideas were always novel."), and the target was related to the contextually-irrelevant but more dominant meaning (e.g., *BOOK*). Participants were slower and made more errors in rejecting targets when these referred to cognate meanings relative to non-cognates.

Another study by Arêas da Luz Fontes and Schwartz (2010) showed that even an offline task can demonstrate how homograph meanings in one language influence the other. In this study, Spanish-English bilingual participants generated meanings for English homographs. The results showed that the weaker meaning of a polarized homograph was more likely to be produced if it was shared in Spanish, making it less polarized. For example, the weaker meaning of *arms* (i.e., weapons) is shared in Spanish, which boosted the rate at which this meaning was produced. The authors concluded that being a bilingual alters the way that they conceptualize words. The studies described here have a few limitations. First, the only examined the use of homographs, which have identical lexical form. It is unclear if similar coactivation of meanings will occur when translations are not similar in form. Also, the words used have distinct unrelated meanings. It is possible that the nature of the effects may be faciliatory when multiple senses of a word are related.

PRESENT STUDY AND OVERALL STRATEGY

Research has yet to systematically examine the extent to which activation spreads across multiple senses of words across languages. Also, relatively little research has tested the assumptions of models like the DFM in pure comprehension tasks. In the present study we examined the extent to which activation spreads to multiple senses of words that are either shared or not shared across languages during comprehension, and whether the strength of the spread of this activation is modulated by overlap in lexical form. To assess if activation spreads across the multiple senses of words across languages, we developed a priming paradigm in which polysemous words were presented twice, first in the context of one of their senses, and then again in the context of the alternative sense. We manipulated whether the two presentations were in the same or different language and the cognate status of the polyseme. In Experiment 1, polysemous words were presented out of a sentence context in word pairs. In the prime word pair, the polyseme was presented with a word that biased the intended (weaker) sense, then in the target word pair the polyseme was presented with a word that biased the other (dominant) sense. In critical trials, the sense being activated changes across presentations of the polyseme. In control trials, the same meaning is being activated twice. For Experiment 2, polysemes were presented in a surrounding sentence context where each clause biased a different sense. The first mention of the polyseme occurred in the first clause of the sentence, and this clause only biased the weaker meaning, while the second mention of the polyseme occurred in the second clause of the sentence and biased the dominant meaning. Participants see the same word presented in the sentence twice with a different sense biased at each presentation in critical sentences. Control sentences present the same word across clauses with the same meaning being biased.

Hypotheses and Predictions

The central hypothesis guiding the present experiments is that activation spreads across the multiple senses of words across languages. Therefore, we predicted that semantic verification in Experiment 1 and reading times in Experiment 2 would be facilitated for targets compared to primes when critical words are presented within or across languages. We also hypothesized that the relative strength of activation across senses is modulated by whether the sense is shared across languages. Therefore, we predicted that semantic verification in Experiment 1 and reading times in Experiment 2 would be facilitated for polysemes with shared senses relative to non-shared senses. Finally, we hypothesized that strength of activation across senses would be modulated by the overlap in lexical form. Therefore, we predicted that semantic verification in Experiment 1 and reading times in Experiment 2 would be facilitated for cognate polysemes compared to non-cognate polysemes.

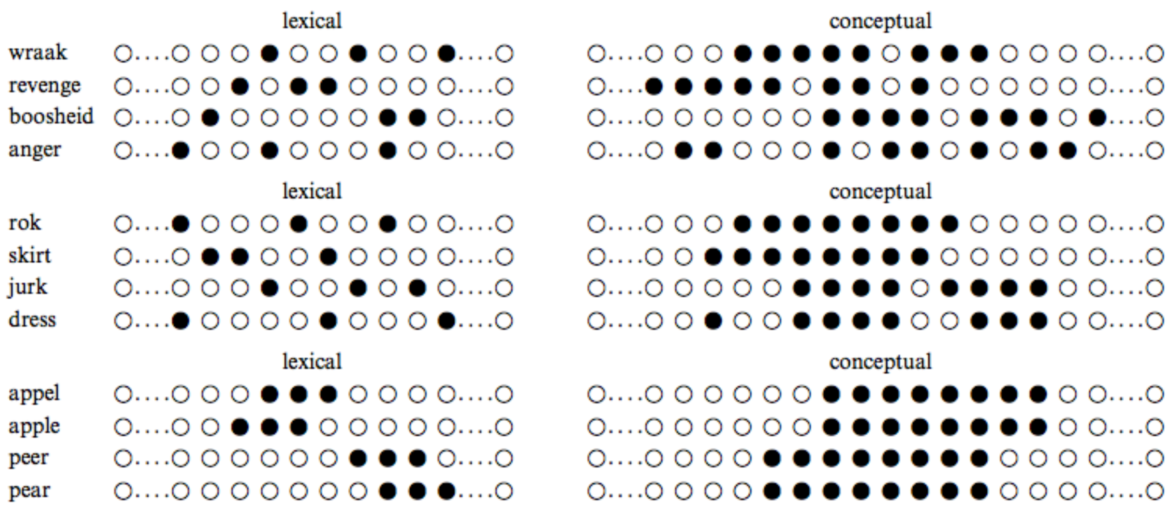


Figure 1.1: Pictorial representation of the DFM adopted from van Hell and de Groot (1998).

Chapter 2: Experiment 1

The first experiment investigated the extent to which accessing/retrieving a word sense in one language spreads activation to other senses of the word within and across languages when words were presented without a surrounding sentence context. The general approach consisted of presenting bilingual participants with word pairs containing a polysemous word, and a word that instantiated one of its senses (e.g., easy - hard) in a semantic relatedness task. The polysemous word was repeated with another word that instantiated a different sense (e.g., soft - hard) either in the same or different language.

METHOD

Participants

A power analysis was conducted and revealed that based on a complete within-groups comparison an ideal sample size of 62 participants will be needed to achieve power at the 0.8 level, assuming a small effect size of .15.

Data was collected from a total 73 participants (62% female). The average age was 21.84 (SD = 5.40), and 96% were Hispanic. Participants were proficient Spanish-English bilinguals recruited mainly from the Psychology department's online participant pool (SONA). The experimenter employed additional recruitment strategies such as visiting classrooms in the Psychology department and posting flyers around campus. Compensation was either course credit or monetary.

Language dominance was determined based on the age equivalency scores from the picture naming and passage comprehension subtests of the Woodcock-Muñoz Language Survey Revised (Woodcock, Muñoz-Sandoval, Ruef, & Alvarado, 2005). The higher score on the picture naming subtest was classified as the dominant language, if the scores were the same in both languages, then the higher score on the passage comprehension subtest determined dominance. Based on this procedure forty-two participants were classified as English dominant and 31 as Spanish dominant (see Table 1)

Additional language background information such as age of acquisition and other language usage statistics were collected using the English-Spanish Proficiency and Dominance Assessment (ESPADA; Francis & Strobach, 2013). The average age of acquisition (AoA) for English was 10.83 (SD = 5.14), and the average AoA for Spanish was 4.89 (SD = 4.00). Participants rated their speaking and reading abilities on a scale of 1 (more proficient in English) to 7 (more proficient in Spanish). The average speaking proficiency was 3.67 (SD = 2.00), and the average reading proficiency was 3.42 (SD = 1.69).

Design

The proposed experiment was based on a 2 (language of prime word pair; L1 vs. L2) x 2 (language of target; L1 vs. L2) x 2 (equivalency of senses; shared vs. not shared) x 2 (cognate status of polyseme; cognate vs. non-cognate) within-subjects design. Example words fulfilling the language of prime and target conditions can be found in Table 2. Participants' accuracy and latencies for semantic relatedness decisions were recorded during the priming task.

Materials and Stimuli

Polysemes

An initial pool of English polysemous words were chosen for this study through a variety of means such as looking through published studies, self-generating words, and enlisting the help of colleagues. A subset of words were used from the following studies: Frazier and Rayner (1990), Rodd et al. (2002), Hino and Lupker (1996), Klein and Murphy (2001), Klepousniotou (2002), Verspoor and Lowie (2003), Williams (1992), and Twilley, Dixon, Taylor, and Clark

(1994). From these studies and self-generating other words (eliminating duplicates), a total of 223 words were compiled as the initial pool. Words with low frequency senses were eliminated, leaving a total stimulus set of 105 polysemes. It was not possible to equate all conditions on frequency and still have enough items for all conditions. A t-test was conducted to compare frequency of polysemes with shared and not shared senses. No significant difference was found, $p = .07$. Another t-test conducted to compare the frequency of polysemes were cognates and non-cognates. No significant difference was found, $p = .28$.

Norming procedures were conducted with the selected polysemes to establish: (1) the relative frequency with which the alternative senses are used, (2) which senses are used in Spanish versus those that are exclusive to English and, (3) the perceived relatedness of the different senses based on responses provided by a bilingual sample drawn from the same target population as the critical experiments.

To assess the relative frequency and equivalency of the senses across languages eighteen participants were presented with two pairs of sentences containing the polyseme, one pair in English and the other in Spanish. Each sentence of the pair biased one of the senses of the polyseme. Participants were asked to rate each sentence based on how often they used the target word in that way (1 = always, 5 = never). If they chose never, they were asked to give an alternative word they would use instead. See Table 4 for a set of example sentences used for norming.

To assess the perceived relatedness of the senses of the polysemes seventeen participants were presented with a pair of sentences, with each sentence biasing one of the senses. They were asked to rate how related in meanings the two target words were (1 = a great deal, 5 = not at all). Polysemous words had an average relatedness of 3.19 (SD = .77).

Word pairs

There were three types of word pairs, polyseme word pairs, non-polyseme, control pairs and unrelated pairs. English and Spanish versions of all pairs were created, and the language of the words within each pair was always the same.

Each polyseme was paired with two words, one related to each of its two senses. The related words were selected from the Small World of Words database (De Deyne, Navarro, Perfors, Brysbaert, & Storms, 2018). All pairs were translated into Spanish. Words within the pairs were always kept in the same language

Fifty non-polysemous words were paired with two words that were both related to its one meaning. For example, *flames – fire* and *torch – fire* were a set of prime and target word pairs fulfilling this condition. An additional 155 words were paired with two unrelated words.

Proficiency Measures

One measure of language proficiency used in the proposed study was the Woodcock-Muñoz language survey revised (Woodcock et al., 2005). This survey was an objective measure of Spanish and English language proficiency. There were a total of seven sections in this survey, but the two of interest to the current study were picture vocabulary and passage comprehension. These sections are completed in both English and Spanish for each participant. In both of these sections, the items progressively got harder. Participants continued with that section until they could not complete any items on a page; they completed all the items incorrectly, or they administered all items in a given section.

In the picture vocabulary section, participants were presented with pictures and were asked to name them to the best of their ability. There were a total of 59 pictures; each picture named correctly earned the participant one point. In the passage comprehension section, participants were presented with a short passage ranging from 1 to 3 sentences that contained a blank. The participants' job was to fill in the blank with the most appropriate word. All blanks were to be filled in with a single word. There were a total of 33 passages; each passage completed correctly earned the participant one point. Each subtest was scored separately, and for each subtest you can obtain an equivalent age based on the score they earned.

An additional language survey used is the ESPADA (Francis & Strobach, 2013). This survey was a self-report measure that asked a number of questions to assess language proficiency and dominance for Spanish-English bilinguals living near the US-Mexico border. The first section asked general language background information such as when they started learning both languages and how many years were they educated in either language. The next section asked the participant to self-rate their language abilities. One question of particular interest to the researchers asked the participants to rate which language they feel more proficient in when they are speaking, listening, reading, and writing. Participants indicate their answers on a Likert scale (1 indicating higher proficiency in English to 7 indicating higher proficiency in Spanish). The final section of the survey asked a series of questions to assess in which language participants typically communicate and how often they are exposed to each language.

Apparatus

The priming task was presented on a computer using E-prime 2.0 software. Responses were made regarding the semantic relatedness of the words in each pair (e.g., Are the pair of words related in meaning?). Decisions were made using a button box.

Procedure

Experimental session procedure

When participants arrived, their bilingual status was verbally confirmed. Once it was confirmed they were a Spanish-English bilingual, they were asked for their written consent. Participants completed the computer portion of the experiment in an individual testing room. They were seated in front of a computer screen with a button box placed in front of them. Instructions were given before the task begins. They were instructed that they will be presented with word pairs. They were asked to decide if the words in each pair are related in meaning. Responses were made on the button box. Experimenters verbally repeated the instructions to the participants and answer any questions they may have. Participants completed 10 practice trials and then 310 trials experimental trials. After the experimental task participants completed the ESPADA and Woodcock-Muñoz language measures. After completing the language measures, participants were debriefed and thanked for their time.

Trial procedure

Trials consisted of a prime word pair and a target word pair. The second word of each pair was always the same. For the polyseme trials, the prime pair was always related to the lower frequency sense and the target pair was always the pair related to the higher frequency sense. This sequencing was chosen to ensure that the lower frequency sense would in fact be activated, since previous research with homonyms has shown that when one meaning is of much higher frequency than the alternative, the time to access the dominant meaning may not be sufficient for activation to spread to the subordinate meaning., while the language of the two pairs was either in the same or different language. The pairs in each set were either in the same or different language. The two words within each pair were always in the same language, but the language across pairs varied to create four different language conditions: English-English, Spanish-Spanish, English-Spanish, Spanish-English. All possible language conditions of the word pair sets were rotated through four experimental running lists.

For each trial, a fixation cross was presented until the participant pressed the middle button on the button box. This was followed by the prime pair. The word pair was presented on the screen simultaneously. It was presented until the participant responded or 3000 ms had elapsed. Next, a fixation cross was presented for 100 ms. Then the target pair was presented simultaneously until the participant responded or until 3000 ms had elapsed. This sequence repeated for each trial (see Figure 2).

Analyses and Data Trimming

Data trimming procedures

For all participants' data, response latencies under 300 ms were removed. Additionally, any response latencies 2.5 SDs above the participant's average were removed from final analyses.

Approach of analysis

Linear and logistic mixed-effects regression approaches were applied to response latency data to accommodate the random effects of participants and items simultaneously (Baayen, Davidson, & Bates, 2008). These analyses were implemented in R using the lme4 package. The maximal random effects structure under which the model converged was used. For RT, unstandardized linear regression coefficients are reported. For all analyses, English and Spanish response languages were recoded as L1 and L2 according to each participant's objective language dominance based on picture naming scores from the Woodcock-Muñoz language survey revised (Woodcock et al., 2005).

RESULTS

General Effects of Sense Priming

To test for general priming effects response latencies and accuracy of responses to prime and target word pairs were submitted to separate linear mixed-effects regression models with language of the pair (L1 versus L2), trial type (prime versus target word pairs) and word pair condition (whether the word pair contained a polysemous word or not) as within-subjects fixed effects. The models included random intercepts for participants and items and random slopes for language of the pair, trial type, and word pair condition.

Response latencies

For the model of response latencies, there was a main effect of language of the pair, reflecting faster responding to pairs in L1 compared to L2, $b = 153.86$, $SE = 28.13$, $t = 5.49$, $p < .001$. The main effect of trial type was also significant, indicating faster responding to target trials relative to prime trials, $b = -175.47$, $SE = 10.61$, $t = -16.53$, $p < .001$. There was also a main effect of word pair condition, with longer latencies to word pairs containing a polysemous word, relative to non-polysemous word pairs $b = 133.40$, $SE = 24.07$, $t = 53.54$, $p < .001$. This was qualified by a significant interaction with trial type, indicating a greater reduction in reaction times between prime and target trials for word pairs containing a polyseme relative to non-polysemous pairs, $b = 40.35$, $SE = 15.89$, $t = -2.54$, $p = .01$. See Figure 3. This suggests that activation does in fact spread to the multiple senses of polysemous words. Also, since this two-way interaction was not qualified by language the extent of this activation is similar in an L1 and an L2.

Accuracy

For the model on accuracy, correct and incorrect responses were coded as 1's and 0's respectively and submitted to a logistic mixed-effects regression model with the same fixed and random effects structure as used for the RT analysis. There was a main effect of trial type indicating target trials had higher accuracy rates compared to prime trials, $b = .42$, $SE = .11$, $z = 3.95$, $p < .001$. There was a main effect of word pair condition reflecting higher accuracy rates for word pairs containing non-polysemous words compared to polysemous word pairs, $b = -.70$, $SE = .18$, $z = -3.86$, $p < .001$. Additionally, there was a significant interaction of word pair condition and trial type such that there was a greater increase in accuracy scores between prime and target trials for word pairs containing a polyseme relative to non-polysemous pairs, $b = .60$, $SE = .11$, $z = 5.93$, $p < .001$, (see Figure 4). This provides convergent evidence that activation spreads across the multiple senses of polysemous words. Word pair condition also interacted significantly with language, $b = -.38$, $SE = .10$, $z = -3.71$, $p < .001$ (see Figure 4). This interaction reflected a greater decrease in accuracy in the L2 for word pairs containing a polyseme relative to non-polysemous pairs, which was not evident in the accuracy rates for pairs in the L1. No other interactions were significant.

Comparing Sense Priming Within and Across Languages

To test whether the magnitude of sense priming differs within versus across languages, latencies and accuracy of responses for target word pairs only were submitted to separate linear mixed-effects regression model with language of the pair, language match (whether the language of the target pair was the same or different as the preceding prime pair) and word pair condition (whether the word pair contained a polysemous word or not) as within-subjects fixed effects. The model included random intercepts for participants and items and random slopes for language of the pair, language match, and word pair condition.

Response latencies

In the analysis on response latencies, there was a main effect of language, with faster responding to target pairs in L1 compared to L2, $b = 158.12$, $SE = 33.05$, $t = 4.79$, $p < .001$. There was also a main effect of language match, with faster latencies to target pairs that were in the same language as the preceding prime pair, $b = -130.54$, $SE = 25.68$, $t = -5.08$, $p < .001$. This was qualified by a significant interaction with word pair condition, $b = 148.85$, $SE = 50.36$, $t = 2.96$, $p = .004$, reflecting the fact that latencies were shortest when target word pairs were in the same language as prime pairs and did not contain a polysemous word. The mean latencies for polysemous and non-polysemous word pairs across the two language match conditions are displayed in Figure 3 along with the latencies to polysemous and non-polysemous prime pairs as a baseline comparison. As can be seen in the figure, the reduction in response latencies to target pairs with polysemes was similar across language match and mismatch conditions. This suggest that the strength of the spread of activation to multiple senses of polysemous words is similar within and across languages. No other main effects or interactions were significant.

Accuracy

The analysis on accuracy of responses revealed a significant main effect of language indicating higher accuracy rates for target pairs in L1 compared to L2, $b = -.52$, $SE = .19$, $z = 2.93$, $p = .007$. There was a main effect of language match with higher accuracy rates for target pairs that were in the same language as the preceding prime pair, $b = .31$, $SE = .11$, $z = -2.70$, $p = .003$. The two-way interactions between language match and word pair condition, $b = -.95$, $SE = .11$, $z = -6.68$, $p < .001$, and language match with language of the target pair, $b = .53$, $SE = .13$, z

= 4.11, $p < .001$, were both significant; however, these were qualified by a three-way interaction between language of the target pair, language match, and word pair condition, $b = -1.05$, $SE = .25$, $z = -4.14$, $p < .001$. Figure 4, panel A displays the mean accuracy rates for target pairs in the L1 along with those for prime pairs as a baseline comparison. Panel B displays the same means for L2 pairs.

As can be seen in the figure, accuracy rates in L1 and L2 yielded a significant interaction of language match and word pair condition. In both languages when prime and target word pairs were in the same language, word pairs containing a non-polyseme had greater accuracy rates than word pairs containing a polyseme. However, in when prime and target pairs were in differing languages, word pairs containing a polyseme had greater accuracy rates than word pairs containing a non-polyseme. Accuracy rates are boosted when word pairs containing a polyseme are in different languages.

Effect of Cognate Status on Sense Priming

To test whether the magnitude of sense priming is modulated by cross-language lexical form overlap, latencies and accuracy of responses to polysemous target word pairs were submitted to separate linear mixed-effects regression models. Analyses were restricted to polysemous pairs only because there was not a sufficient number of cognate non-polysemous pairs to analyze. The models included language of the pair, language match, and cognate status (whether the polysemous word was a cognate or not) as within-subjects fixed effects. The models included random intercepts for participants and items and random slopes for language of the pair, language match, and cognate status.

Response latencies

The analysis on response latencies revealed a main effect of language of the pair such that faster response times were observed for pairs in L1 compared to L2, $b = 147.10$, $SE = 30.00$, $t = 4.90$, $p < .001$. There was a main effect of language match indicating faster responses times to targets presented in the same language as the prime, $b = 124.00$, $SE = 8.35$, $t = 14.85$, $p = .002$. More critically, there was a significant interaction between cognate status of the polyseme and language of the pair, $b = 54.19$, $SE = 27.58$, $t = 1.97$, $p = .05$. As can be seen in Figure 5, this interaction reflected the fact that, in the L1, there was a cost in processing time for pairs with cognate polysemes relative to noncognate polysemes. This suggests that retrieving one sense of a cognate polyseme (when processing the prime pair) produced competition when retrieving the alternative senses of the polyseme, irrespective of whether that prime pair was in the same or different language. Although latencies were much longer to L2 pairs, no cost of cognate status was observed. Cognate status also interacted significantly with language match, $b = 42.29$, $SE = 14.27$, $t = 2.96$, $p = .003$. As can be seen in Figure 5, there was a consistent cost in processing time for target cognate polysemes relative to noncognate polysemes, this cost was greater when the target pair was presented in a different language than the preceding prime. This suggests that competing activation spreads across the various senses of polysemes, the strength of which is greatest when polysemes have a high degree of lexical form overlap across languages.

Accuracy

The analysis on accuracy of responses revealed a main effect of language of the pair such that word pairs in L1 elicited higher accuracy rates compared to L2 word pairs, $b = -.44$, $SE = .11$, $z = -3.98$, $p < .001$. There was also a main effect of language match indicating that higher accuracy rates were elicited for trials where the prime and target were in the same language compared to where trials were in different languages, $b = -.60$, $SE = .03$, $z = -19.49$, $p < .001$. As with the analysis on response latencies, there was a significant interaction between cognate status and language match, $b = -.17$, $SE = .05$, $z = -3.11$, $p = .002$. As can be seen in Figure 6, the pattern was similar to that observed in latencies, with evidence of competing activation of multiple senses of polysemous words across languages.

Effect of Sense Status on Sense Priming

To test whether the magnitude of sense priming is modulated by whether both senses of an English polysemous word were shared or not in Spanish, response latencies and accuracy of responses to polysemous word pairs were submitted to separate linear mixed-effects regression model with language of the pair, language match, and sense status (whether the word senses were shared across both languages or not) as within-subjects fixed effects. The model included random intercepts for participants and items and random slopes for language of the pair, language match, and sense status.

Response latencies

The analysis on response latencies revealed a main effect of language of the pair such that faster response times were elicited when word pairs were in L1 compared to L2, $b = 154.69$, $SE = 29.79$, $t = 5.19$, $p < .001$. There was a main effect of language match indicating that faster response times were elicited for trials where the prime and target were in the same language compared to where trials were in different languages, $b = 132.46$, $SE = 8.08$, $t = 16.40$, $p = .002$. There we no significant main effects or interactions with sense status. These results suggest that senses can be primed similarly, regardless of whether they are shared across both languages or not.

Accuracy

The analysis on accuracy revealed was a main effect of language of the pair with higher accuracy rates for word pairs in L1 compared to L2, $b = -.44$, $SE = .11$, $z = -4.03$, $p < .001$. There was also a main effect of language match indicating higher accuracy rates were elicited for trials where the prime and target were in the same language compared to where trials were in different languages, $b = -.66$, $SE = .03$, $z = -21.50$, $p < .001$. There was a main effect of sense status reflecting higher accuracy rates for polysemous word pairs with shared senses compared to not shared senses, $b = .35$, $SE = .16$, $z = 2.22$, $p = .03$. No other significant effects were found.

DISCUSSION

This experiment was conducted to test the central hypothesis guiding the present experiment was that activation of one sense would spread to another related sense within and across languages. Results from this experiment supported this hypothesis. Specifically, there was an interaction of word pair condition and trial type where response times were reduced from prime to target word pairs, and this reduction was greater for polysemes than non-polysemous words. Because this two-way interaction was not qualified by language, it suggests that multiple senses of a word can be primed, and that priming was equal across L1 and L2. Accuracy results support this finding as well. There was an interaction of word pair condition and trial type where accuracy responses increased from prime to target word pairs, and this gain was greater for polysemes than non-polysemous words. Also, there was evidence suggesting that word senses can be primed across languages. The significant interaction of language match and word condition demonstrated that the reduction in response latencies to target pairs with polysemes was similar across language match and mismatch conditions. This suggest that the strength of the spread of activation to multiple senses of polysemous words is similar within and across languages.

It was further hypothesized that the strength of activation could be modulated by overlap in lexical form across languages (comparing cognates versus noncognates) and overlap in meaning across languages (comparing responses to senses that are shared versus not shared). Results from the experiment supported the hypothesis that spread of activation across senses is in fact modulated by lexical form overlap. Specifically, the interaction of language of the pair and cognate status of the polyseme reflected the fact that, in the L1, there was a *cost* in processing time for pairs with cognate polysemes relative to noncognate polysemes. This suggest that retrieving one sense of a cognate polyseme (when processing the prime pair) produced competing activation of the alternative senses of the polyseme, irrespective of whether that prime pair was in the same or different language. This same pattern was observed for accuracy responses. Additionally, there was an interaction of language match and cognate status indicating that there was a consistent cost in processing time for target cognate polysemes relative to noncognate polysemes. This cost was greater when the target pair was presented in a different language than the preceding prime. This suggests that competing activation spreads across the various senses of polysemes, the strength of which is greatest when polysemes have a high degree of lexical form overlap across languages. This same pattern was observed for accuracy responses.

We did not find support for the hypothesized role of sense overlap. However, the lack of interactions with sense status indicates that senses, whether shared or not, can be primed similarly.

This was the first experiment to directly test the assumption of the DFM that states that conceptual features that are only appropriate in one language may come to be linked to the word form in the opposite language due to activation flow throughout the network. However, polysemes were presented as isolated word pairs. A surrounding sentence context may restrict the extent to which activation spreads because the word sense will be more strongly activated. The goal of Experiment 2 was to examine the potential effect of a sentence context.

Table 2.1: Experiment 1 Average Woodcock-Muñoz Picture Naming Age Equivalencies

	English Score	Spanish Score
L1 of English	14	9
L1 of Spanish	8	13

Table 2.2: Experiment 1 Example Words Fulfilling Language Conditions

Language	Prime	Target
English – English	sad – blue	color – blue
Spanish – Spanish	afligido – triste	color – azul
English – Spanish	sad – blue	color – azul
Spanish – English	afligido – triste	color – blue

Note: Blue is an example of a polysemous word in English that does not share both meanings in Spanish. The sense being activated changes across prime and target word pairs.

Table 2.3: Experiment 1 Stimuli Characteristics for English Words

	Polysemous words				Non-polysemous words
	Not shared		Shared		
	Non-cognate	Cognate	Non-cognate	Cognate	
N	51	11	19	24	55
Frequency	88.42 (108.61)	70.18 (87.36)	107.82 (78.15)	143.29 (155.63)	57.65 (108.76)
Length	4.72 (.98)	5.45 (1.81)	4.47 (1.26)	5.63 (1.58)	5.29 (1.46)
Relatedness	3.48 (1.29)	3.25 (1.46)	2.84 (1.40)	3.24 (1.28)	NA

Note: Average values are reported with standard deviations reported in parentheses.

Table 2.4: Example Sentences Used for Norming

Polysemous Word	Sense	Sentence
Date	calendar	Look at the calendar to find today's **date**.
Date	romantic	I'm going on a **date** tonight with my boyfriend.
Date	calendar	Mira al calendario para saber la **fecha** de hoy.
Date	romantic	Voy a ir a una **fecha** esta noche con mi novio.

Note: The words in shown in bold were the target words for which participants gave their ratings.

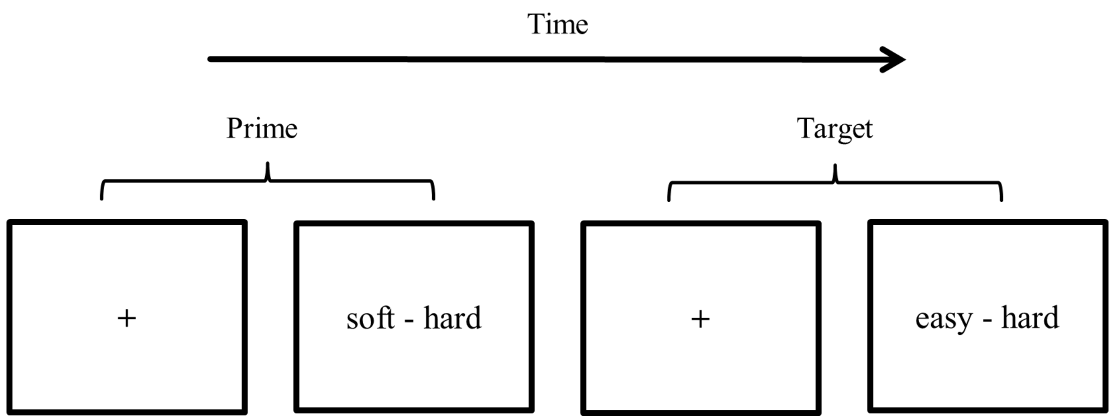
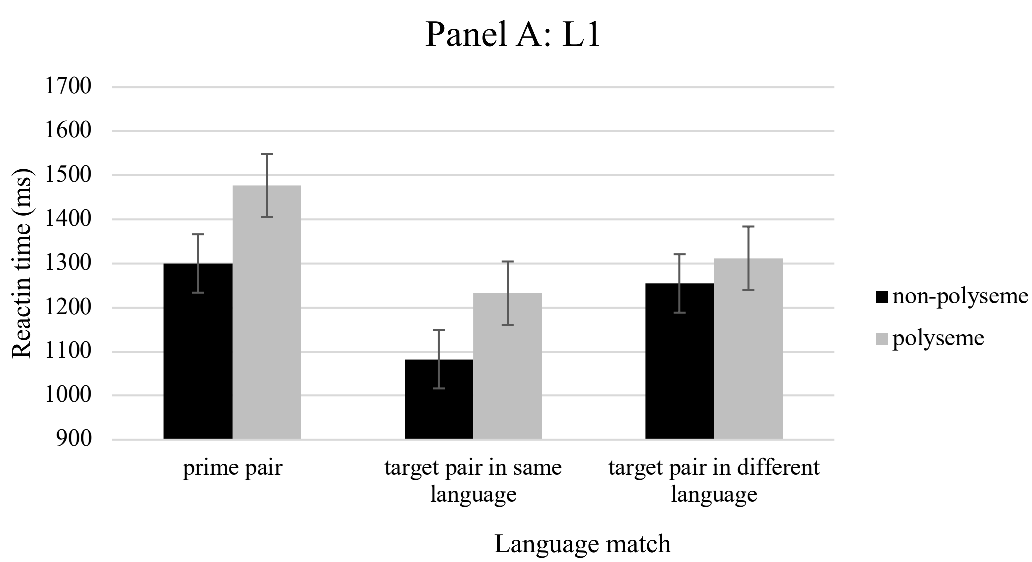


Figure 2.1: Schematic of an experimental trial for Experiment 1. For non-experimental trials, the same meaning is being activated across prime and target word pairs.



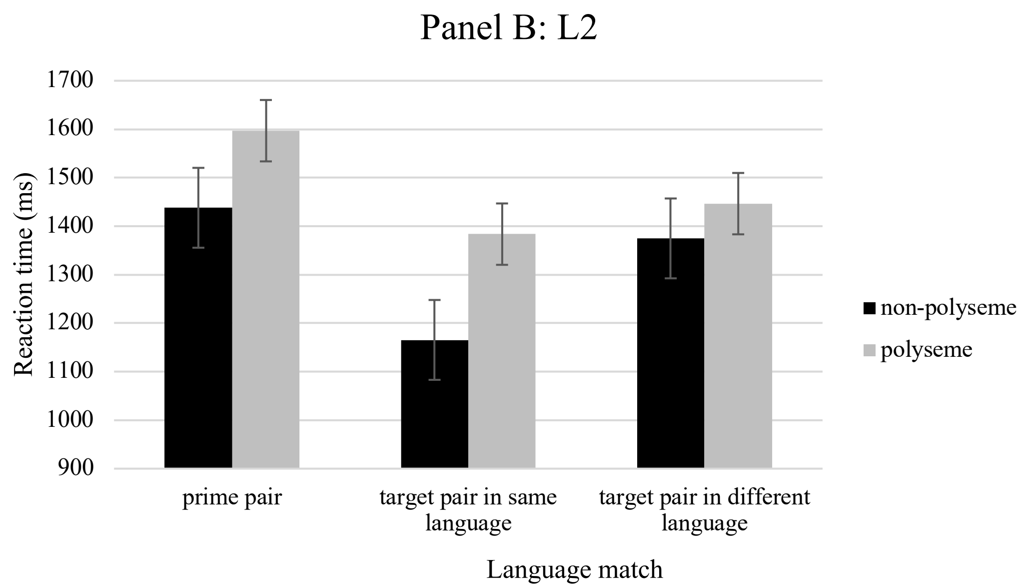
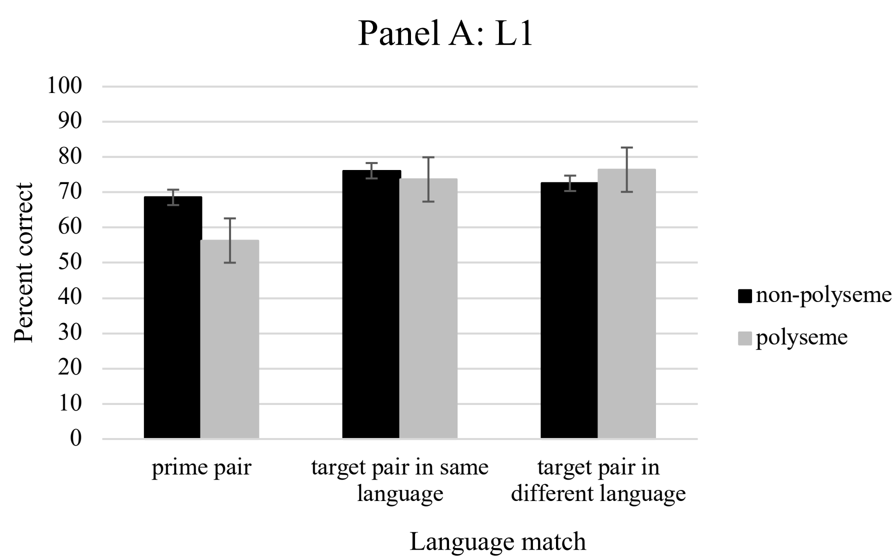


Figure 2.2: Interaction of language of the pair, language match, and word pair condition for response latencies in Experiment 1. Error bars reflect standard error.



Panel B: L2

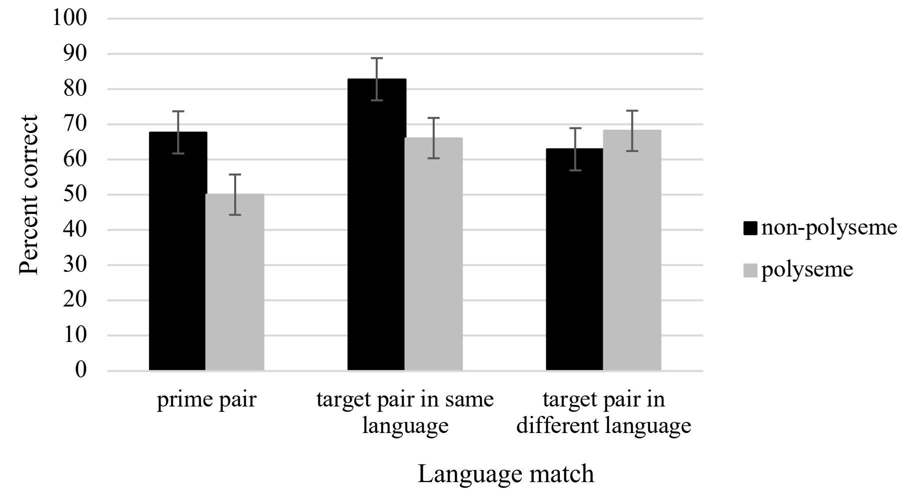
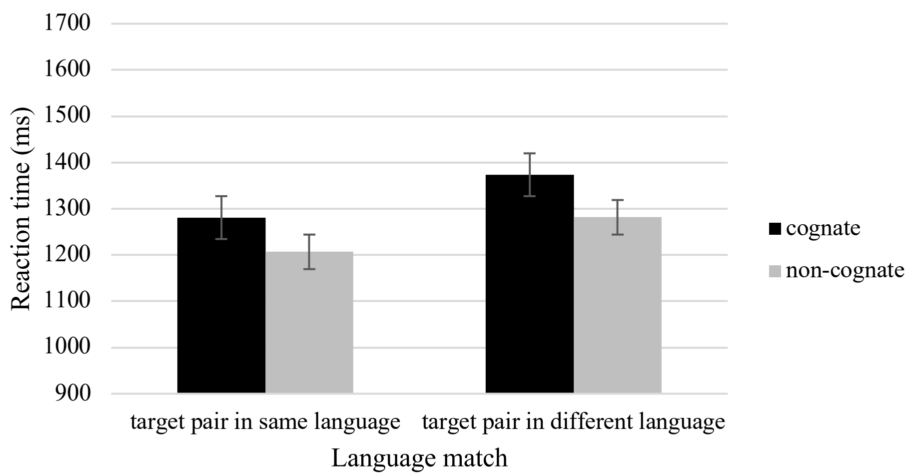


Figure 2.3: Interaction of language of the pair, language match, and word pair condition for accuracy scores in Experiment 1. Error bars reflect standard error.

Panel A: L1



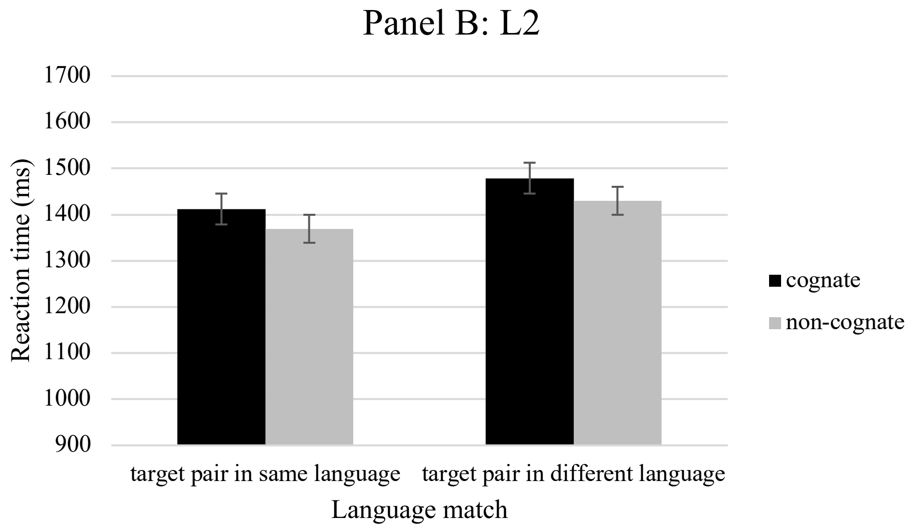
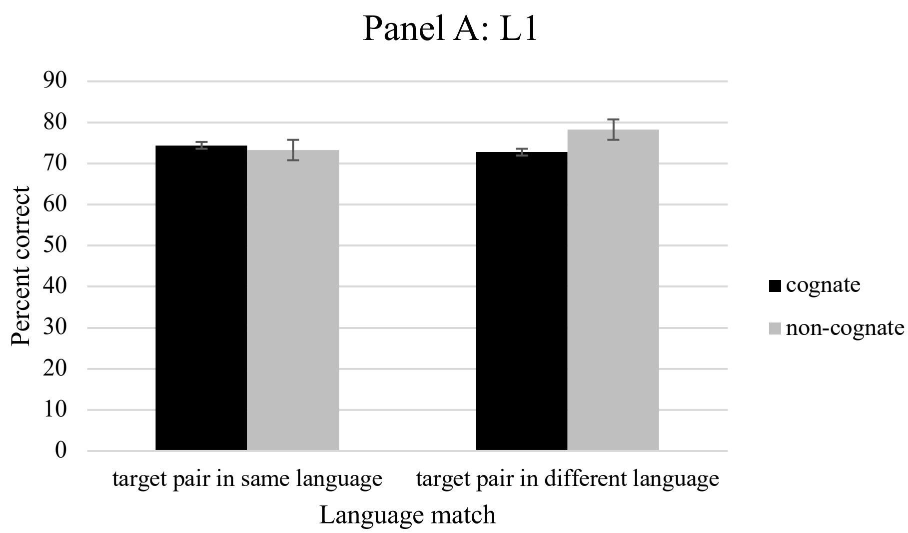


Figure 2.4: Interaction of language of the pair, language match, and cognate status for response latencies in Experiment 1. Error bars reflect standard error.



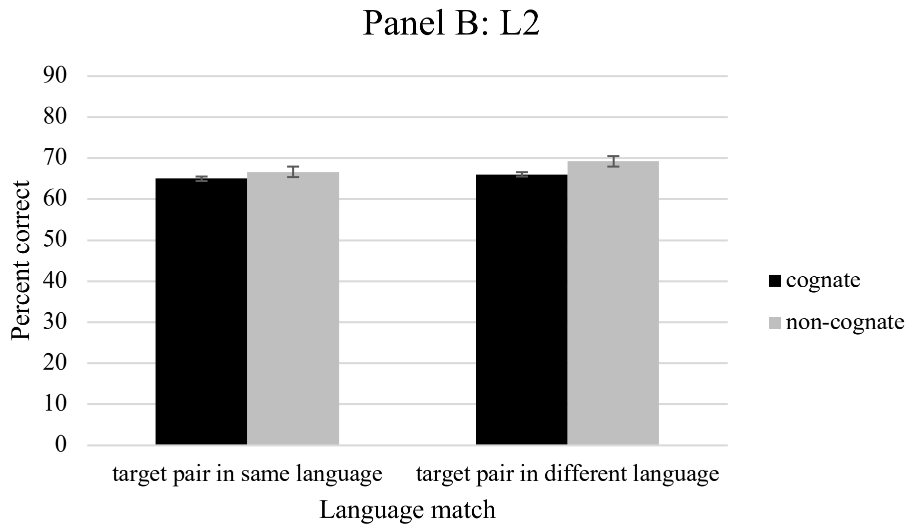


Figure 2.5: Interaction of language of the pair, language match, and cognate status for accuracy scores in Experiment 1. Error bars reflect standard error.

Chapter 3: Experiment 2

The second experiment investigated the extent to which accessing/retrieving a word sense in one language spreads activation to other senses of the word within and across languages when words were presented in a surrounding sentence context. The general approach consisted of presenting bilingual participants with sentences instantiating both senses of a polysemous word.

METHOD

Participants

Participants from the same population as Experiment 1 were recruited for Experiment 2. There were a total 80 proficient Spanish-English bilingual participants (72% female). The average age was 21.82 (SD = 5.96), and 97.5% were Hispanic. Based on scores from the WMLS-R, 43 participants were English dominant and 37 were dominant in Spanish. The average AoA for English was 7.49 (SD = 4.19), and the average AoA for Spanish was 1.84 (SD = 1.67). The average speaking proficiency was 3.96 (SD = 1.88), and the average reading proficiency was 3.53 (SD = 1.56). The majority of the participants had mothers who completed some college (21.62%) or earned a 4-year degree (22.52%) and had fathers who completed high school (20.72) or completed some college (20.72) (see Table 5).

Design

Experiment 2 was based on a 2 (language of prime; L1 vs. L2) x 2 (language of target; L1 vs. L2) x 2 (equivalency of senses; shared vs. not shared) x 2 (cognate status; cognate vs. non-cognate) within-subjects design. Prime and target words were presented in a sentence context in the same or different language.

Dependent measures consisted of four eye-movement measures. First fixation duration was the length, in milliseconds of the first fixation made on a target region or word, and gaze duration was the aggregate time of all fixations made on a target region or word before moving forward in the text. Total reading time was the total time) of all fixations made on a word or target region, including regressive fixations made after proceeding forward in the text. It is reflective of post-word-identification processes that are implicated with text integration. The number of regressive eye-movements made back to the target region was also counted.

Materials and Stimuli

Critical words

The same polysemes and non-polysemous words from Experiment 1 were used.

Stimulus sentences

Sentences consisted of two clauses, in which the critical word (polyseme or non-polysemous control) was repeated. The language of the two clauses varied across all four possible language combinations (English-English, Spanish-Spanish, English-Spanish, Spanish-English). For sentences containing a polyseme, the first clause biased the lower frequency sense and the second clause biased the higher frequency sense (e.g., *The couple wanted to try some hot and spicy delicacies while enjoying their time in hot, humid Thailand*.). Sentences for the non-polysemous words were constructed in a similar manner, but the same meaning was instantiated across the two clauses (e.g., *My little brother plays with model trains for fun; he started doing this after we took a train ride on vacation*.) See Table 6 for example sentences.

All sentences were presented in Arial font size 20. Text was left aligned from the top corner.

Norming

Sentences were normed to ensure they presented a set of coherent ideas and were easy to read. Participants were asked to read through the sentences and rate how coherent the ideas presented in the sentence were (1 = very coherent, 5 = not at all coherent) and how easy to read the sentence was (1 = very easy to read, 5 = not at all easy to read). On average, participants rated the sentences as 2.23 (SD = .56) on the coherency scale. The range extended from 1.25 to 3.25. The average readability score was 1.92 (SD = .64), and the scores ranged from 1 to 3.5.

Apparatus

The EyeLink 1000 eye-tracking system was utilized in the present study because the eye-movement record provided a rich source of data that allowed for a finer-grained and detailed analysis of lexical processing then reaction-time based measures. During the experiment, the eye's pupils were tracked through a rapid camera system, placed at the bottom of the computer monitor. Participants were asked to sit in front of the computer screen with their head placed on a chin rest (see Figure 7). The eye-calibration process took approximately 3 minutes.

Procedure

When participants arrived, their bilingual status was verbally confirmed. Once it was confirmed they were a Spanish-English bilingual, they were asked for their written consent. First, the participants were asked to complete the Woodcock-Muñoz language measure.

Next, if the experimenter notices that participants are wearing heavy eye makeup, they were asked to remove it and were provided an eye makeup removing wipe. Next, participants experienced the eye-tracking portion of the experiment in a well-lit individual testing room. They will be seated in front of a computer screen with their chin placed in the chin rest. The camera system is placed just below the computer monitor (See Figure 7). Participants were instructed on the nature of the task. They were told that they would be reading sentences. Before the task could begin, the eye-tracking system must be calibrated to their eyes. During this process, the participant was asked to follow a moving dot on the screen by only moving their eyes. Calibration took approximately 3 minutes.

The experimental task began after calibration. Participants were shown sentences following the format previously described. The entire sentence was displayed at one time on the top half of the screen. All sentences were presented in Courier New font size 20. Text was left aligned from the top corner. Reading was self-paced. When finished, they were instructed to press the space bar on the keyboard to continue. Following each sentence, participants were presented with a screen that asked them to press the space bar continue. Then the next sentence was shown. After reading 5 sentences, they were be asked a true/false comprehension question regarding the sentence they just read. They were told to press "A" for true and "L" for false. Then they were given the opportunity to take a break. Participants read a total of 210 sentences and answered 40 comprehension questions.

After completing the computer task, participants were asked to complete the ESPADA. Participants were then debriefed and thanked for their time.

Analyses and Data Trimming

Data trimming procedures

For all participants' data, first fixation durations, gaze durations, and total reading times under 100 ms were removed. Additionally, any first fixation durations, gaze durations, and total reading times 2.5 SDs above the overall average were removed from final analyses.

Approach of analysis

The same approach to linear and logistic mixed-effects modeling was used as in Experiment 1.

Results

Comprehension Check Data

Accuracy was recorded for all comprehension questions. Participants with accuracy 70% or below had their data excluded from analyses. This led to 5 participants' data being excluded. The remaining 80 participants had an average accuracy of 87.58% (SD = 6.19).

General Effects of Sense Priming

To test for general effects of sense priming, durations to the first mention and second mention of critical polysemes and non-polysemous control words were submitted to a linear mixed-effects regression models with language of the mention (L1 versus L2), language switch (whether the language of the sentence remained the same or switched between the two mentions), position of mention (first versus second mention in the sentence), and polysemous status (whether the word was polysemous or not) as within-subjects fixed effects. The model included random intercepts for participants and items and random slopes for language of the word, position of mention, and polysemous status. First fixation durations, gaze durations and total reading times were submitted to different models.

First fixation duration

The analysis on first fixation duration revealed a main effect of position of mention with shorter durations made on second mentions than first mentions, $b = -2.92$, $SE = 1.16$, $t = -2.53$, $p = .01$. There was also a main effect of language of the mention with shorter durations for L1 mentions relative to L2 mentions, $b = 7.97$, $SE = 1.28$, $t = 6.24$, $p < .001$. There was a significant main effect of polysemous status with shorter durations made on non-polysemous words relative to polysemous words, $b = 2.96$, $SE = 1.40$, $t = 2.13$, $p = .03$. Additionally, there was a significant interaction of language of the mention and polysemous status (see Figure 8), $b = 4.33$, $SE = 1.71$, *t* = 2.53, *p* = .01. L2 polysemous words were read more slowly than L2 non-polysemous words, while there were no differences between polysemous and non-polysemous words in L1. There was also a three-way interaction between language of the mention, language switch, and position of mention, *b* = -6.71, *SE* = 3.42, *t* = -1.96, *p* = .049 (see Figure 8). Durations did not differ across first and second mentions in L1, irrespective of language switch or non-switch. A different pattern was observed for mentions in L2. While durations did not differ for first and second mentions across a language switch, there was a large reduction in durations from first to second mention in the same language. This pattern suggests that durations from first and second mentions presented solely in L2 benefited most from the spread of activation in the network.

Gaze duration

In the analysis on gaze duration there was a main effect of position of mention such that second mentions had shorter durations than first mentions, *b* = -17.72, *SE* = 2.73, *t* = -6.50, *p* < .001. There was also a main effect of language of the mention indicating that L1 mentions had faster durations than L2 mentions, *b* = 34.31, *SE* = 4.58, *t* = 7.49, *p* < .001. There was a significant main effect of polysemous status, such that non-polysemous words were read faster than polysemous words, *b* = 10.46, *SE* = 4.05, *t* = 2.58, *p* = .01. There was also an interaction of language of the mention and position of the mention (See Figure 9), *b* = -12.79, *SE* = 3.22, t = -3.97, *p* < .001. A greater reduction in durations was observed from first to second mention in L2 compared to L1. This pattern suggests that mentions presented in L2 benefited more from spread of activation throughout the network leading to a greater reduction in durations between first and second mentions. Additionally, there was an interaction of language of the mention and polysemous status (see Figure 9), *b* = 6.98, *SE* = 3.22, *t* = 2.17, *p* = .03. L2 non-polysemous words received shorter durations than L2 polysemous words, while there were no differences between durations for polysemous and non-polysemous words in L1. The interaction of polysemous status and position of mention was not significant, Figure 9 demonstrates a reduction in durations that is similar for polysemes and non-polysemes. The meaning instantiated actually changes across the first and second mention for the polysemes, and the fact that the reduction is similar in magnitude to non-polysemes suggests that there is in fact spread of activation to multiple senses of polysemous words.

Total reading time

The analysis on total reading time revealed a main effect of position of mention such that second mentions had shorter reading times than first mentions, $b = -48.49$, $SE = 8.67$, $t = -5.59$, $p < .001$. There was also a main effect of language of the mention indicating that L1 mentions had faster reading times than L2 mentions, $b = 96.21$, $SE = 13.75$, $t = 7.00$, $p < .001$. There was a significant main effect of polysemous status such that non-polysemous words were read faster than polysemous words, $b = 34.55$, $SE = 12.98$, $t = 2.66$, $p = .008$. There was also a significant interaction of language of the mention and position of the mention (see Figure 10), $b = -48.01$, $SE = 7.70$, $t = -6.24$, $p < .001$, reflecting a greater reduction in reading times from first to second mention in L2 compared to L1. This pattern further suggests that mentions presented in L2 benefited more from spread of activation throughout the network leading to a greater reduction in durations between first and second mentions. The interaction of polysemous status and position of mention was not significant, Figure 10 demonstrates a reduction in durations that is similar for polysemes and non-polysemes. The fact that the reduction of polysemes is similar in magnitude to non-polysemes suggests that there is in fact spread of activation to multiple sense of polysemous words.

Effect of Cognate Status on Sense Priming

To test whether the magnitude of spread of activation of multiple senses is modulated by cross-language overlap in lexical form, first fixation durations, gaze durations and total reading times of polysemous words were submitted to separate linear mixed-effects regression model with language of the mention (L1 versus L2), language switch (whether the language of the second mention was the same or different as the preceding first mention), and cognate status (whether the polysemous word was a cognate or not) as within-subjects fixed effects. The model included random intercepts for participants and items and random slopes for language of the mention, language switch, and cognate status.

First fixation duration

The analysis on first fixation duration revealed a main effect of language of the mention indicating that mentions in L1 had shorter durations than L2 mentions, $b = 10.05$, $SE = 1.51$, $t = 6.64$, $p < .001$. There was also a significant interaction of language switch and cognate status (see Figure 11), $b = -5.76$, $SE = 2.33$, $t = -2.47$, $p = .01$. Cognates presented across a language switch took less time to read than non-cognates. Additionally, cognates presented in the same language took longer to read than non-cognates. This pattern suggests that that there is competing activation across multiple senses of cognates, when the language is kept consistent.

Gaze duration

The analysis on gaze duration revealed a main effect of language of the mention indicating that mentions in L1 had shorter durations than L2 mentions, $b = 36.10$, $SE = 5.50$, $t = 8.22$, $p < .001$. There was also a significant interaction of language of the mention and cognate status (see Figure 12), $b = 9.45$, $SE = 4.37$, $t = 2.16$, $p = .03$, reflecting that L2 cognates took less time to read than L2 non-cognates, while no differences were observed between cognates and non-cognates in L1.

Total reading time

The analysis on total reading times revealed there was a main effect of language indicating that mentions in L1 had shorter reading times than L2 mentions, $b = 98.34$, $SE = 14.64$, $t = 6.72$, $p < .001$. There was also a main effect of cognate status such that cognates were read faster than non-cognates, $b = 38.83$, $SE = 20.08$, $t = 1.93$, $p = .05$. Figure 13 contains means for all levels of each factors included in this analysis.

Effect of Sense Status on Sense Priming

To test whether the magnitude of spreading activation of multiple senses is modulated by whether both senses of an English polysemous word were shared or not in Spanish, first fixation durations, gaze durations and total reading times of polysemous words were submitted to separate linear mixed-effects regression model with language of the mention (L1 versus L2), language switch (whether the language of the second mention was the same or different as the preceding first mention), and sense status (whether the word senses were shared across both languages or not) as within-subjects fixed effects. The model included random intercepts for participants and items and random slopes for language of the mention, language switch, and sense status.

First fixation duration

The analysis on first fixation duration revealed there was a main effect of language of the mention such that mentions in L1 had shorter reading times than L2 mentions, $b = 9.91$, $SE = 1.48$, $t = 6.69$, $p < .001$.

Gaze duration

The analysis of gaze duration revealed a significant main effect of language of the mention reflecting that mentions in L1 had shorter reading times than L2 mentions, $b = 36.63$, $SE = 4.36$, $t = 8.40$, $p < .001$. There was also a main effect of sense status indicating that polysemes with shared senses were read faster compared to polysemes that did not have shared across both languages, $b = -12.13$, $SE = 5.84$, $t = -2.08$, $p = .04$. This was qualified by a significant interaction of language of the mention and sense status (see Figure 14), $b = -10.82$, $SE = 4.20$, $t = -2.57$, $p = .01$. Words with shared and not shared senses did not have differing durations in L1, but a different pattern emerged in L2. Words with not shared senses took significantly longer to read than shared senses. This pattern suggests that spread of activation is weaker across the L2 especially when a sense is specific to one language.

Total reading time

The analysis of total reading times indicated there was a significant interaction of language of the mention reflecting that mentions in L1 had shorter reading times than L2 mentions, $b = 99.81$, $SE = 14.51$, $t = 6.88$, $p < .001$. There was also a main effect of sense status indicating that polysemes with shared senses were read faster compared to polysemes with senses that weren't shared across both languages, $b = -36.19$, $SE = 17.45$, $t = -2.07$, $p = .04$. This pattern was not observed in Experiment 1 results and suggests that activation of sense status information is reflected in post-lexical integration.

DISCUSSION

This experiment was conducted to test whether spread of activation would extend to multiple senses of a word in a sentence context. If activation spread to multiple senses, it is the case that the nature of the spread of activation is similar or different to that observed out of context.

Several results from Experiment 2 provide evidence that activation spreads across multiple senses of words in a sentence context. First, gaze durations and total reading times for polysemous words were reduced from the first to second mention. Furthermore, this reduction was similar to that observed for non-polysemous words. This is particularly striking since the two mentions of the polysemous words instantiated different senses, whereas the two mentions of non-polysemous words were semantically consistent. There was also evidence that the spread of activation across a polyseme's multiple senses benefits L2 more than L1. Specifically, gaze durations and total reading times were reduced from first to second mentions in L2 while there were no differences across positions of mention in L1.

Results from the analysis on first fixation and gaze duration supported the hypothesis that spread of activation across the multiple senses of polysemes is modulated by lexical form overlap. Specifically, first fixation durations were longer for cognate polysemes when the language of the sentence was kept consistent. This suggests that retrieving one sense of the cognate polyseme spread competing activation to the other sense, and the effect of this competition was greatest when cognate polyseme was repeated in the same language.

There was also evidence suggesting that sense status modulated the extent to which activation flowed across multiple senses of a word. Words with shared and not shared senses did not have differing durations in L1, but in L2, polysemes with not shared senses took significantly longer to read than shared senses. This pattern suggests that activation is slower to spread across the L2 especially when a sense is specific to one language. This effect was only significant in gaze duration suggesting that sense status does not initially become activated, but also this information does not remain active for long.

Table 3.1: Experiment 2 Average Woodcock-Muñoz Picture Naming Age Equivalencies

	English Score	Spanish Score
L1 of English	14	9
L1 of Spanish	6	10

Table 3.2: Experiment 2 Example Sentences Fulfilling Language Conditions

Language	Prime	Target
English – English	The couple wanted to try some hot and spicy delicacies while enjoying their time in hot, humid Thailand	
Spanish – Spanish	La pareja quería probar algunos manjares picosos y condimentados mientras disfrutaban de su tiempo en la cálida y húmeda Tailandia.	
English – Spanish	The couple wanted to try some hot and spicy delicacies mientras disfrutaban de su tiempo en la cálida y húmeda Tailandia.	
Spanish – English	La pareja quería probar algunos manjares picosos y condimentadios while enjoying their time in hot, humid Thailand.	

Note: The sense being activated changes across first and second mentions of the polysemous word.

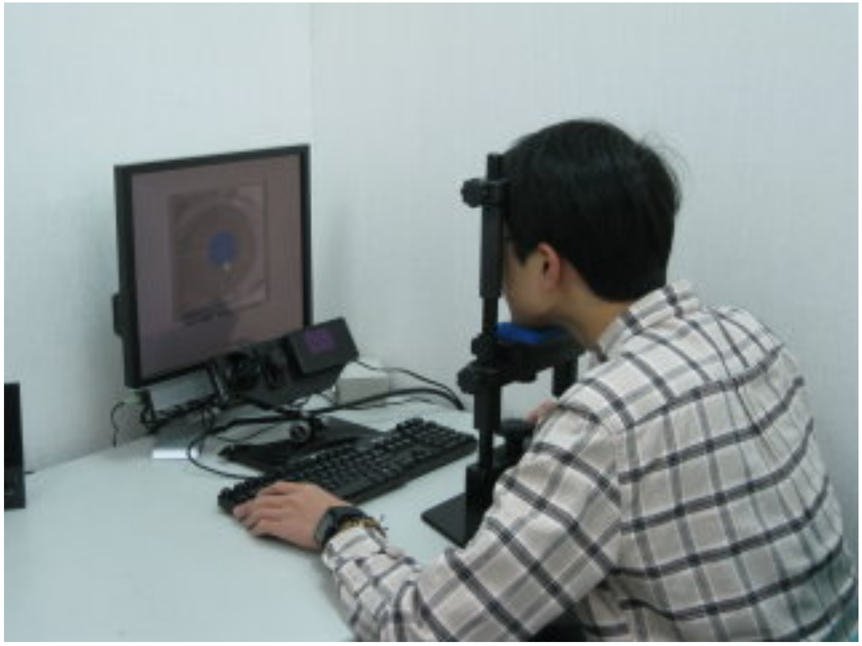
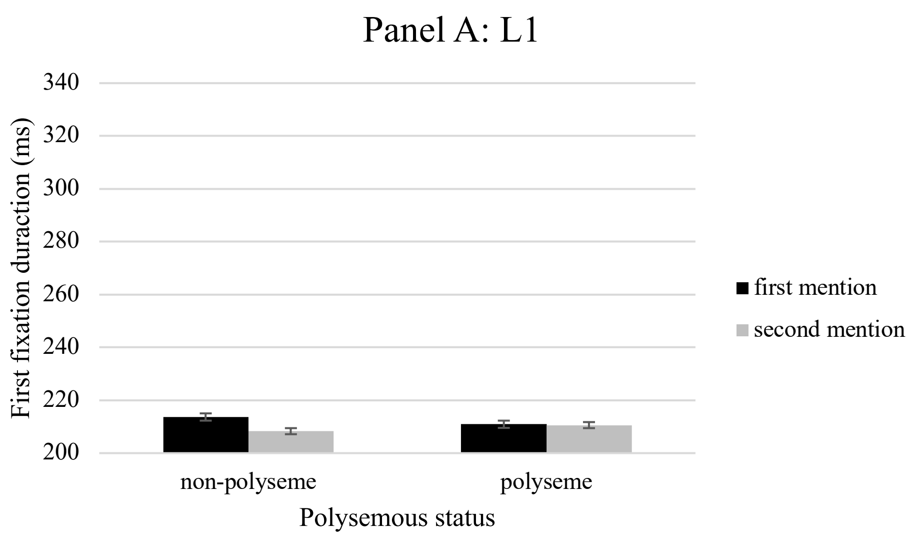


Figure 3.1: Display of how the eye-tracking system is arranged.



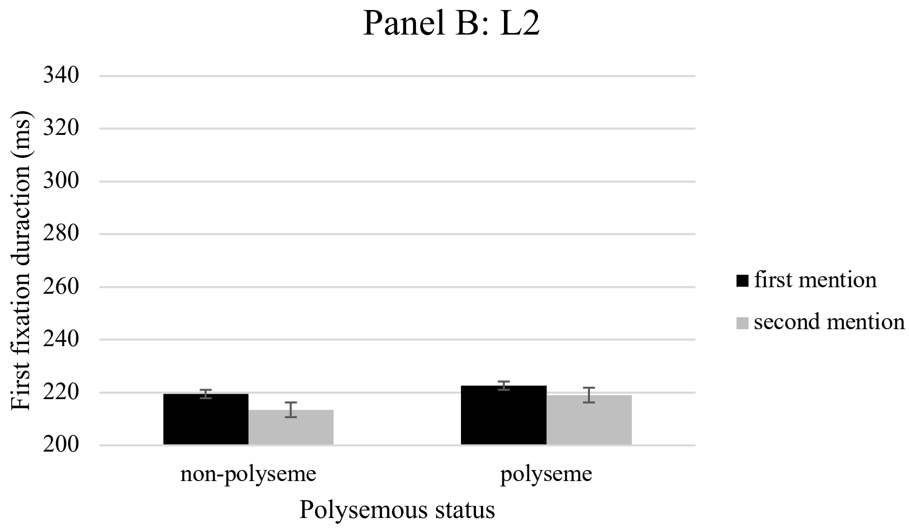
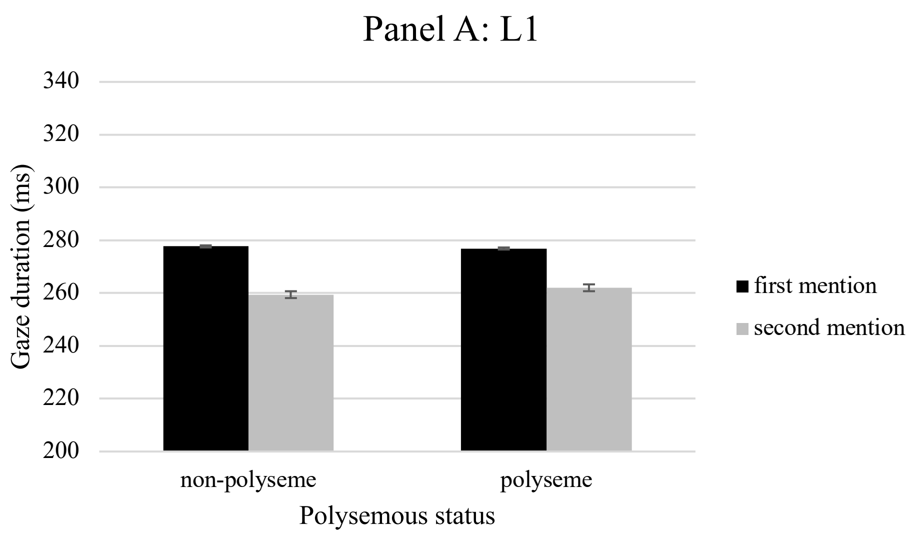


Figure 3.2: Interaction of language of the mention, polysemous status, and position of mention for first fixation duration in Experiment 2. Error bars reflect standard error.



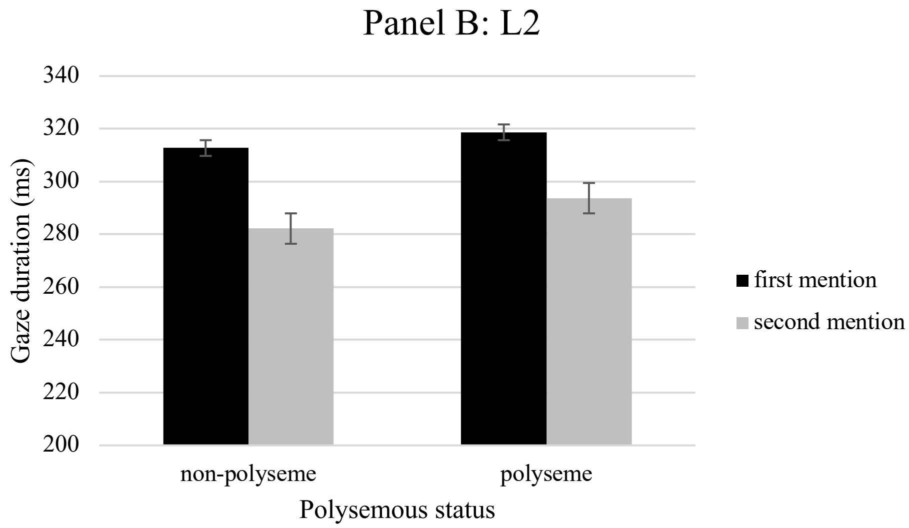
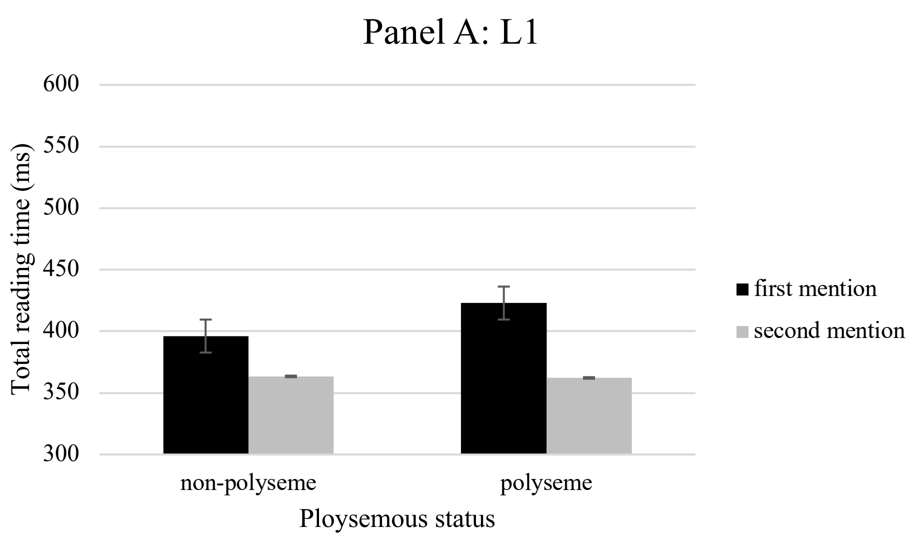


Figure 3.3: Interaction of language of the mention, polysemous status, and position of mention for gaze duration in Experiment 2. Error bars reflect standard error.



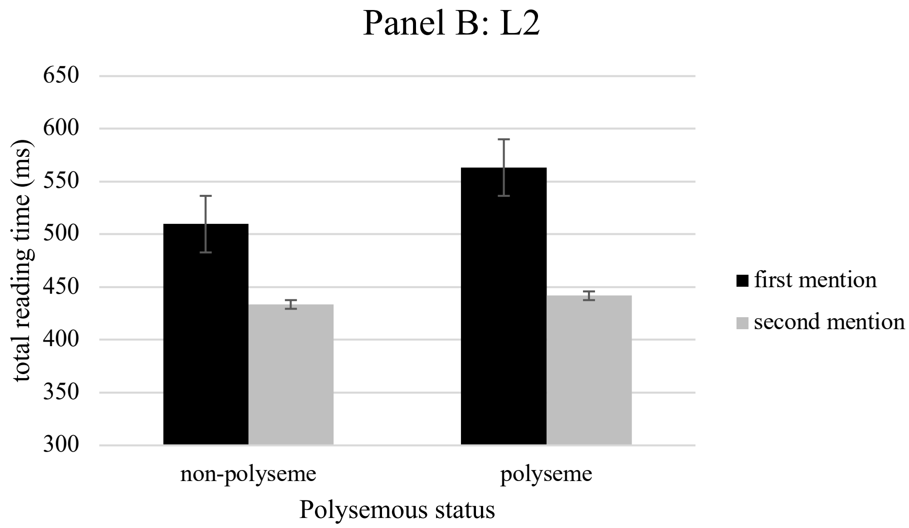
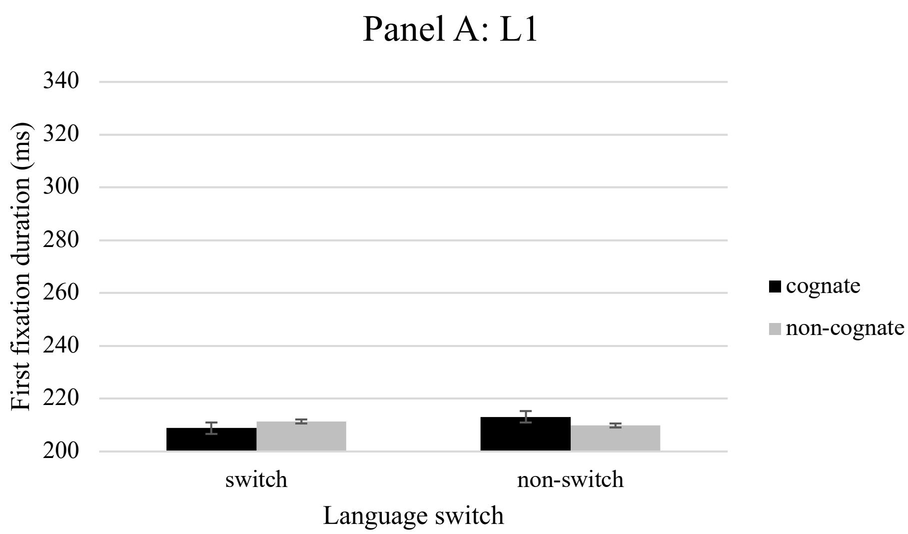


Figure 3.4: Interaction of language of the mention, polysemous status, and position of mention for total reading time for Experiment 2. Error bars reflect standard error.



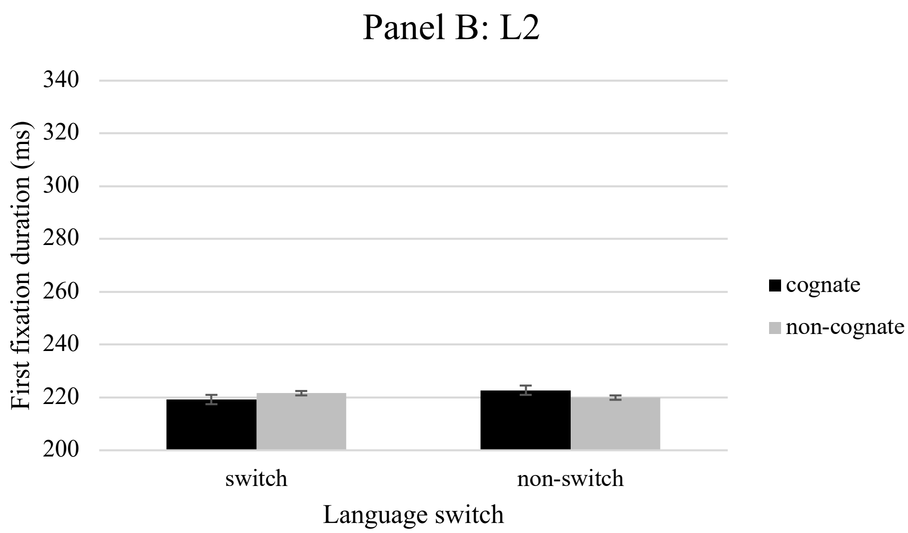
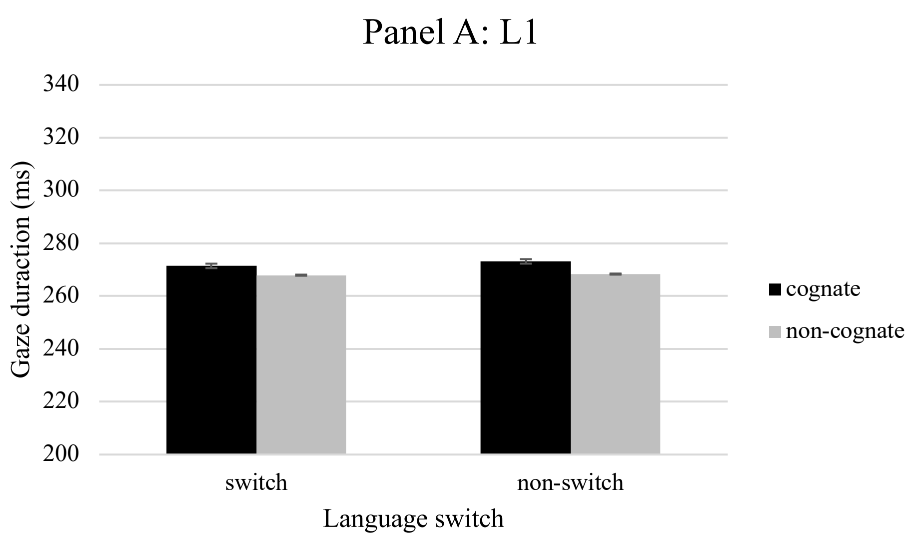


Figure 3.5: Interaction of language of the mention, language switch, and cognate status for first fixation duration in Experiment 2. Error bars reflect standard error.



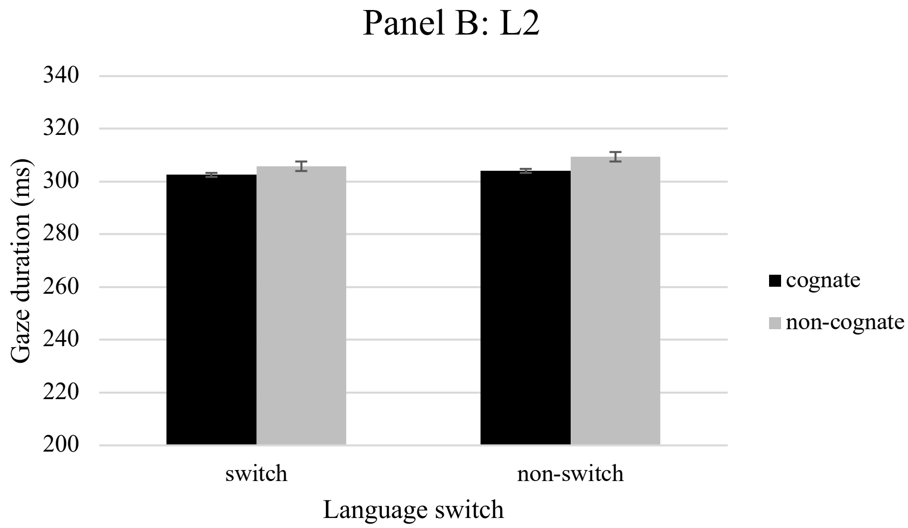
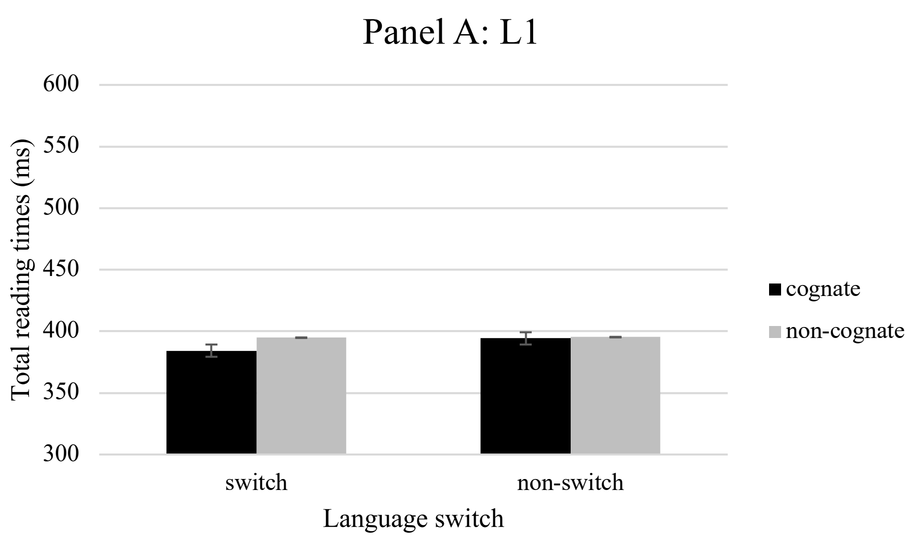


Figure 3.6: Interaction of language of the mention, language switch, and cognate status for gaze duration in Experiment 2. Error bars reflect standard error.



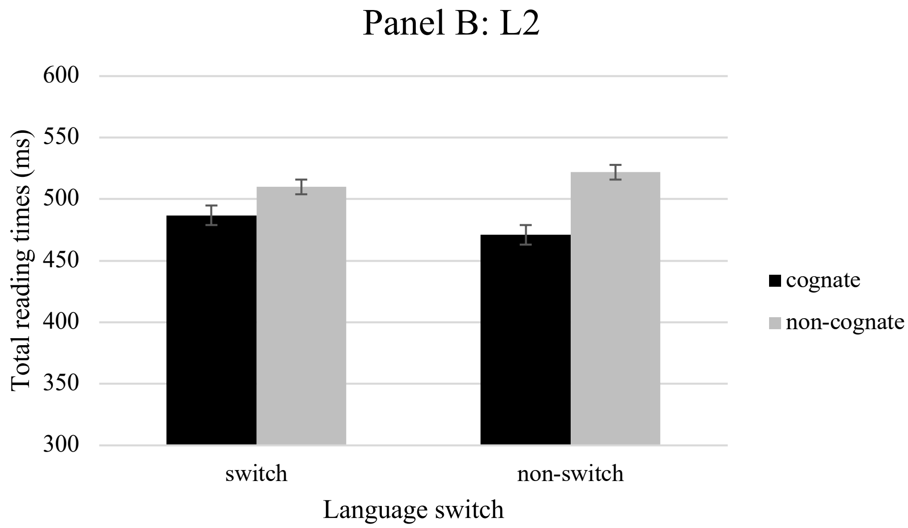


Figure 3.7: Interaction of language of the mention, language switch, and cognate status for total reading time in Experiment 2. Error bars reflect standard error.

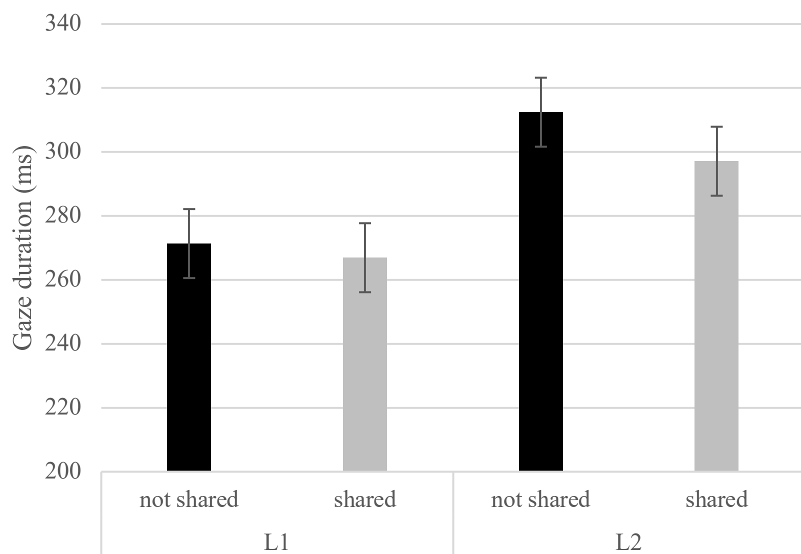


Figure 3.8: Interaction of language of the mention and sense status for Experiment 2. Error bars reflect standard error.

Chapter 4: General Discussion

Overall, both experiments provide evidence that there is spread of activation across the multiple senses of polysemous words within and across languages. In Experiment 1, semantic verification performance was facilitated in latency and accuracy for target word pairs containing a polyseme relative to prime pairs. Furthermore, the magnitude of priming was similar for same-language and different language trials, suggesting that the spread of activation is similar within and across languages, with similar reductions irrespective of the match in language between the pairs. This suggests that conceptual features of different senses are strongly linked to word form features across languages. Experiment 2 provided evidence that sense priming occurs within and across languages in sentence context. All reading measures were reduced, suggesting that spread of activation affected pre lexical access processes and post lexical integration processes. The reduction in reading times for polysemes was similar to that of non-polysemous control words; even though in the former case the clauses biased different senses of the critical word. Together these results provide strong support for the assumption of the DFM that conceptual features, even those that are not shared across languages, are connected within an interactive network. In fact, we did not find any evidence that no-shared conceptual features have weaker connections to word forms across languages as proposed by the model. This may be because the non-overlapping conceptual features pertained to related senses of a word. A reduction in priming across languages may be observed for words whose meanings are unrelated.

Results from both experiments converge suggesting that form overlap has an effect on spread of activation in the form of competition. In Experiment 1, non-cognates showed facilitated latencies compared to cognates. This effect lends evidence for cognate competition as latencies were slower when the word pair contained a cognate compared to a non-cognate. In the word pairs, the weaker sense was always activated with the prime pair. Having initially retrieved the weaker sense spread activation to the dominant sense leading to competition and slower latencies. The shared form overlap boosted activation in the form of competition to the dominant sense. This same pattern of activation occurred for cognate polysemes presented in the same language in Experiment 2. Being presented with the same word twice when it was a cognate, strongly activated both senses. Switching those senses across presentations caused competition, which was heightened when it was all within language and/or a cognate.

From these results we have further support for the DFMs interconnectivity of lexical features. Cognate polysemes create a situation where lexical features map onto competing conceptual features, which compete with one another especially when the sense being activated is changed across presentations, and the weaker sense is activated initially. This pattern was observed for both experiments and is consistent with spreading activation in the DFM's interconnective network. In Experiment 2, the effects of form overlap were strongest in first fixation duration. First fixation duration is indicative of initial spread of activation. As is known from the BIA+ (Dijkstra & Van Heuven, 2002), activation initially spreads to orthographic and phonological features. Cognates overlap greatly in orthography, which could be a cause of the competition observed and explain why these effects are seen more strongly in first fixation duration. This reading measure captures initial lexical activation and could be more sensitive to greater overlap in orthography.

In reference to sense status modulating sense priming, Experiment 1 results did not support this hypothesis. There were no significant interactions with this variable indicating that shared and not shared senses can be primed similarly. This could suggest that in order to see interactive effects of sense status more context is needed than a word pair. Experiment 2 supported this notion; gaze durations were facilitated for polysemes with shared senses in L2. These results suggest that activation of shared senses is stronger than not shared senses in a weaker language. Additionally, this effect was only significant in gaze duration. Gaze duration is indicative of initial lexical activation leading up to retrieval. These results suggest that both senses are strongly activated during gaze duration, but the activation has dissipated by total reading times. Once the meaning of the sentence has been integrated, sense status (shared or not) no longer affects reading measures. These results also indicate that activation is short-lived. Given the sentence context, the sense could be more strongly activated compared to Experiment 1 leading to differing patterns of sense status modulation.

In terms of the DFM, Experiment 2 results indicate that activation is able to spread more readily across shared senses of a polysemous word in a weaker language because the information is linked to both languages. This notion supports the DFM's interconnected network of conceptual features; however, evidence for this was very limited only being observed in that one specific interaction. Taking results from both experiments into account, these results suggest that the DFM's network is less graded than originally thought, and conceptual features that are language specific become linked with the lexical form in the opposite language (i.e., the language that does not use those features).

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Jennifer M. Blush earned her Bachelor of Arts degree in Psychology and German from Southern Illinois University Edwardsville in 2012. In 2015, she received her Master of Arts degree in Psychology from Illinois State University. She joined UTEP's doctoral program in Psychology in 2015.

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