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Bilingual lexical disambiguation in context: The role of non-selective cross-language activation

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The present study tested whether lexical disambiguation in sentence context is affected by cross-language lexical activation. In Experiment 1 Spanish-English bilinguals read English sentences biasing the subordinate meaning of homonyms that were either cognates or non-cognates. Participants' ability to reject follow-up target words related to the dominant meaning showed greatest inhibition when the homonym was a cognate and the dominant meaning was shared with Spanish. In Experiment 2 a separate group of bilinguals read sentences biasing the dominant meaning of the homonyms and were instructed to accept target words related to any meaning of the homonym. In this case cognate status of the homonym facilitated acceptance of targets related to the subordinate meaning when this was shared with Spanish. A monolingual control experiment showed no effects of cognate status on processing. Findings are discussed in terms of expanding current models of lexical disambiguation to account for bilingual processing.

The cognition of reading continues to be a topic of fascination to researchers. Because reading involves the rapid orchestration of many cognitive processes operating on stimuli that are inherently ambiguous, it is the perfect forum for examining the cognitive nature of language and thought. The ambiguity aspect of reading is of particular interest to language researchers because it allows us to explore how the mind first activates multiple representations and then selects or settles on a particular one. While it is true that there is plenty of ambiguity within a single language, an entirely new layer is introduced when there is an additional language within the same cognitive system, as is the case for bilinguals. The study of bilingualism allows researchers to examine ambiguity from the letter level all the way up to the language level in ways not possible with monolinguals.

In the present study we focused on the processing of cross-language ambiguity in sentence context. Currently there is general agreement across models that meaning selection is influenced by semantic information from context but there is much debate regarding the time-course and magnitude of that influence (Binder & Rayner, 1998; Binder & Morris, 1995; Dopkins, Morris, & Rayner, 1992; Duffy, Morris, & Rayner, 1988; Kellas, Paul, Martin, & Simpson, 1991; Paul, Kellas, Martin, & Clark, 1992a; Rayner, Pacht, & Duffy, 1994; Sereno, Pacht, & Rayner, 1992; Simpson & Burgess, 1985; Simpson & Kreuger, 1991). For example, the Reordered Access Model (RAM) (Duffy et al., 1988) assumes that access of homonym meanings is exhaustive and not directly constrained by context. It postulates that the proper role of contextual information is in modulating the relative time-course with which competing meanings become activated. These assumptions have been widely contested by other competing theories and models (Paul, Kellas, Martin, & Clark, 1992b). However, these debates and the theoretical understanding of how context aids in meaning selection is severely limited by the fact that current models are monolingual in their assumptions. That is, their assumptions do not address psycholinguistic dynamics that are specific to bilingualism, such as the role of cross-language lexical activation. We hypothesized that the dynamics of cross-language activation is a critical influence on the time-course and magnitude with which a meaning is activated for bilingual readers. It is therefore of paramount importance that these dynamics be incorporated into current models of lexical disambiguation. In the present paper we present evidence that cross-language activation boosts activation of both dominant meanings (Experiment 1) and subordinate meanings (Experiment 2) in a language-pure sentence processing task. We further propose a way that these findings extend the RAM to bilinguals (B-RAM). We next turn to a review of the relevant literature on ambiguity processing before describing the present study in more detail.

Bilingual lexical access

Overall, research has demonstrated that bilingual lexical access is non-selective in nature. When bilinguals encounter words, lexical candidates from both languages are simultaneously activated. Most of the evidence demonstrating this non-selectivity has come from studies that have incorporated word stimuli that have some type of cross-language lexical ambiguity. For example, many studies have looked at the processing of cognates. Cognates are words that share a high degree of lexical form and have meanings that overlap across languages (e.g., piano/piano in English and Spanish). Therefore, identical cognates are ambiguous in terms of language membership. In general, these studies have found facilitative effects of cognate status (Costa, Caramazza, & Sebastian-Galles, 2000; de Groot & Poot, 1997; de Groot & Keijzer, 2000; Dijkstra, Van Jaarsveld, & Ten Brinke, 1998; Dijkstra, Grainger, & Van Heuven, 1999; Dijkstra & Van Hell, 2003; Gollan, Forster, & Frost, 1997; Lemhöfer, Dijkstra, & Michel, 2004; Van Hell & de Groot, 1998; Van Hell & Dijkstra, 2002). This facilitative effect has largely been interpreted as reflecting the converging activation of the cognate's lexical representations across languages. Since cognates often have identical lexical form it is possible that they might even have a single lexical representation shared across languages. This would imply that their facilitated identification is the result of a higher pooled frequency across languages. However, in two recent trilingual studies (Lemhöfer et al., 2004; Van Hell & Dijkstra, 2002) strong facilitation effects were observed for non-identical cognates, for which a single representation would not be possible. Although cognate facilitation has been observed across many different studies, languages and tasks, there is evidence that when the lexical overlap is not complete, these effects go away or even turn into inhibition (Dijkstra et al., 1999; Schwartz, Kroll, & Diaz, 2007).

Bilingual studies have also examined processing of interlingual homographs. Like cognates, interlingual homographs have a high degree of lexical form overlap across languages but they do not share meaning (e.g., “fin” in Spanish means “end”). Therefore, identical interlingual homographs are ambiguous not only in terms of language membership, but also meaning. Findings regarding interlingual homographs have been mixed. Some studies have demonstrated inhibitory effects associated with homograph status (Dijkstra et al., 1998; Jared & Szucs, 2002; Von Studnitz & Green, 2002) while others have failed to find any effects at all (Gerard & Scarborough, 1989). Furthermore, the specific nature of homograph effects, whether they are inhibitory or facilitative in nature, has varied as a consequence of differences in task demands, the salience of the non-target language, and the relative frequency of the homographs’ lexical representations across languages (Dijkstra, De Bruijn, Schriefers, & Brinke, 2000; Dijkstra, Timmermans, & Schriefers, 2000).

The fact that cognate effects have been much more consistently observed in the literature than interlingual homograph effects suggests that shared semantics boosts activation of the alternative representation from the non-target language. In the present study we capitalized on the existence of ambiguous cognates that have multiple meanings (e.g., novel/novela in English and Spanish). These items can be considered the ideal blend of cognates and homographs: Like unambiguous cognates, there is some semantic overlap, bolstering the degree of cross-language activation. Like homographs, they are also semantically ambiguous (e.g., “novel” in English can mean “a story” or “something new”). This combination allowed us to explore the dynamics of bilingual lexical disambiguation while maximizing the likelihood that any cross-language activation of the irrelevant language lexicon would be observed experimentally, thanks to the shared semantic links.

Lexical ambiguity in sentence context: Monolingual and bilingual studies

It is quite clear from existing research that bilingual lexical access is non-selective in nature. Not only have effects of non-selectivity been found consistently across different paradigms and laboratories, they have also been found to occur irrespective of participants’ language expectations, or language mode (Dijkstra & Van Hell, 2003; Van Hell & Dijkstra, 2002). This leaves us with an important problem. Clearly, bilinguals are capable of selecting a language at some point in order to communicate effectively. How and when is this selection executed? Recently bilingual researchers have started to examine whether the existence of a linguistic context facilitates language selection. Before reviewing this body of work, we will first consider existing monolingual theories on the influence of context on lexical disambiguation. Since most of the research on the effects of sentence context on lexical disambiguation has been based on monolinguals, it provides an important framework for interpreting the more recent bilingual investigations.

Monolingual investigations

The research on monolingual lexical disambiguation in context has a long and rich history, dating back more than 40 years. It is beyond the scope of this paper to cover this literature exhaustively. Instead, we will focus on the studies and models that most directly inform the present investigation. There is general agreement across theories that a sentence context plays an important role in the activation and selection of meanings of ambiguous words. Theoretical differences lie primarily in the assumption regarding how exhaustively all meanings are first accessed. Context-dependent theories assume that selective access of just the target meaning is possible when the context provides adequate information. Context-independent theories assume that all meanings are accessed exhaustively, irrespective of the influences of context. This is a difficult debate to settle since the observation of selective-like patterns of performance does not necessarily rule out the possibility of initial non-selective activation.

It is not the goal of this paper to distinguish between context-dependent and independent theories. Rather our goal is to apply and extend the generally agreed upon theoretical assumptions regarding the influence of context to bilingual reading. Most theories agree that the degree of contextual support for a given meaning as well as its frequency relative to the other meanings are key factors in how early and strongly it will be activated (Binder & Morris, 1995; Duffy, et al., 1988; Duffy, et al., 2001; Tabossi, 1988; Tabossi & Zardon, 1993). The Reordered Access Model (RAM) (Duffy et al., 1988) makes specific predictions regarding how contextual support and meaning frequency interact. According to the RAM, the extent to which the multiple meanings of an ambiguous word compete is dependent on the relative time-course of their activation. The time-course of activation, in turn, depends on the relative frequency of the alternative meanings and the contextual support provided by the sentence. In the absence of a biasing context, the relative frequency of the alternative meanings determines the order (or relative speed) of their activation. However, a strong biasing context can reorder this activation.

Thus, according to this model, initial word access is affected by both lexical and contextual factors. To fully understand this model, consider two types of ambiguous words: balanced and polarized. Balanced ambiguous words are words for which the multiple meanings have a similar likelihood or frequency of use (e.g., fan). Polarized words, on the other hand, contain one meaning that is far more frequent or likely (e.g., novel). In a neutral context, balanced ambiguous words take longer to process than polarized words or unambiguous controls. This is because the two, equally likely meanings compete for selection. For the polarized words, this competition does not occur because the subordinate meaning is not activated early enough.

In a biasing context this pattern is reversed. Balanced words take less time than polarized or unambiguous controls because the target meaning is activated early enough to bypass competition with the alternative. Polarized words however, take longer to process if the context biases the subordinate meaning. This is because the preceding context boosts the activation of the subordinate meaning, allowing it to compete with the dominant meanings. This effect has been referred to as the “subordinate bias effect” (SBE) (Rayner, Pacht, & Duffy, 1994).

This model does an excellent job of accounting for patterns of performance observed across various studies (Dopkins, et al., 1992; Duffy et al., 1988; Duffy, Henderson, & Morris, 1989; Duffy et al., 2001; Rayner et al., 1994; Sereno, O'Donnell, & Rayner, 2006). For this reason, we sought to extend this model to bilingual reading by examining whether the interactions between context and meaning frequency would be further modulated by cross-language activation. The RAM assumes that the dominant meanings of homonyms are always activated and context operates by sometimes allowing other, more subordinate meanings to be activated early enough to compete with the dominant meaning. We hypothesized that, if cross-language lexical representations are activated during reading, competition from dominant meanings homonyms would be even greater if they are shared across a bilingual’s languages. For example, “fast” and “novel” are both polarized English homonyms. However, “novel” is also a cognate with “novela” in Spanish and the dominant meaning is shared across the two languages. Therefore, in Experiment 1 we predicted that we would observe greater competition from the dominant meaning of “novel” than that of “fast”. Using the same logic, in Experiment 2 we predicted that when a subordinate meaning of a polarized cognate homonym (e.g., the weapon meaning of *arm/arma*) is shared across languages, its activation would be boosted, allowing access of that meaning to be facilitated relative to that of a subordinate meaning of a noncognate homonym (e.g., “not eating” meaning of *fast*).

To anticipate the results, findings from the present study supported these predictions, allowing us to update and extend the RAM to bilingual reading by including an additional assumption: the relative time course of meaning activation is influenced by the relative frequency/dominance of a meaning but the order of activation can be re-ordered depending on context and, for bilinguals, cross-language lexical activation. Since our predictions rested on the assumption that there is continued cross-language activation in sentence context, we next turn to a review of bilingual sentence processing and what it suggests about continued non-selectivity in context.

Bilingual investigations

Recent research on bilingual lexical access in sentence context demonstrates that a sentence context can constrain cross-language activation, but its mere presence, in and of itself, does not allow for complete language-selective activation (Altarriba, Kroll, Sholl, & Rayner, 1996; Duyck, Assche, Drieghe, & Hartsuiker, 2007; Elston-Güttler, Gunter, & Kotz, 2005; Schwartz & Kroll, 2006; Libben & Titone, 2009; Van Hell & de Groot, 2008). These studies have identified several factors that influence how constraining a sentence context is on cross-language activation. For example, more language-selective patterns of performance have been observed when the participants have relatively high proficiency in the second language (L2) (Elston-Güttler, Paulmann, & Kotz, 2005; Schwartz & Kroll, 2006) and/or the sentence contexts are highly biasing (Schwartz & Kroll, 2006; Van Hell, 1998; Van Hell & De Groot, 2008). In a recent eye-tracking study, Libben and Titone (2009) observed effects of cross-language activation even in high constraint sentences. However, these effects were restricted to early time-course measures (e.g., first fixation duration). This suggests that the constraining influence of a sentence is greater when the context contains rich semantic information and the reader has the proficiency required to apply this information. Conversely, more language *non*-selective patterns of performance are typically observed when the target word stimuli have a high degree of lexical overlap, particularly semantic overlap (Duyck et al., 2007; Elston-Güttler, 2000; Schwartz & Kroll, 2006; Van Hell & De Groot, 2008). For example, Schwartz and Kroll (2006) found more consistent effects of cross-language activation in low-constraint sentences for cognates then they did for interlingual homographs. Using eye-tracking methodology, Duyck et al. (2007) observed shorter reading times for identical cognates in sentence context, but not for non-identical cognates (e.g., *banaan-banana* in Dutch and English). Elston-Güttler (2000) found no cross-language priming in sentence context between an interlingual homograph and its non-target L1 translation (e.g., *gift-poiso*n; gift means “poison” in German). However, in the same study significant priming was observed when the primes and targets were translations of homonyms from the non-target L1 (e.g., *pine-jaw*; both are translations of “kiefer” in German). This suggests that the cross-language, semantically-based, translational links were more resilient to the constraints of a sentence context than simple form-based links. Therefore it seems that the extent to which a sentence context actually limits cross-language activation depends on whether the critical words share semantic links across languages. However, Van Hell and De Groot (2008) observed that the influence of sentence context was similar when differences in the semantic overlap of the critical items was more subtle (comparing abstract and concrete cognates) rather than absolute (e.g., comparing homographs to cognates).

In summary, the bilingual research demonstrates that a sentence context has a general constraining or attenuating effect on cross-language activation. Given the large body of monolingual literature examining the effects of context on meaning activation of ambiguous words, in the present study we investigated whether a sentence context has a more specific effect on processes of the activation and selection of meanings of L2 words.

One of the earliest studies on L2 ambiguity processing (Frenck-Mestre & Prince, 1997) demonstrated that proficiency plays an important role in the automatic access of an ambiguous word’s meanings. In a primed lexical decision task only highly-proficient bilinguals showed automatic activation of both subordinate and dominant meanings of ambiguous L2 words, while those participants with intermediate proficiency demonstrated automatic access to the dominant meaning only. Similar to that study, we were interested in bilingual processing of L2 ambiguous words, however within a sentential context.

In two recent studies, Elston-Güttler and Friederici (2007; 2005) closely examined bilinguals' processing of L2 homonyms in context. Based on these two studies, the authors describe three phases of L2 disambiguation. Phase 1 refers to early (around 200 MS post-stimulus) spreading activation of a homonym's meanings. This is followed by Phase 2, in which meanings are integrated into the sentential context. Finally in Phase 3, processes of disambiguation are complete. Across both studies, participants read L2 sentences that ended in homonyms (the primes) and then performed a lexical decision on a follow-up target word. On critical trials the target was either related to the contextually appropriate or inappropriate meaning of the homonym prime. Reaction time (RT) and ERP measures were analyzed at the 200, 500 (Elston-Güttler & Friederici, 2005) and 700 MS SOA (Elston-Güttler & Friederici, 2007). While the RT data were quite similar for both natives and non-natives, the ERP data revealed important differences in processing, particularly at the 500 MS SOA. In that SOA, interpreted as reflecting Phase 2 integration processes, non-natives showed priming for both contextually appropriate and inappropriate meanings (as indicated by N400 spikes) while the natives showed this priming for the contextually appropriate meanings only. The critical implication is that non-native readers deactivate inappropriate meanings of homonyms less efficiently than natives during the integration phase of lexical disambiguation.

It has recently been demonstrated that how bilinguals process homonyms in context is further influenced by cross-language lexical activation (Schwartz, Yeh & Shaw, 2008). In that study, highly proficient Spanish-English bilingual read English sentences that biased the subordinate meaning of the final-word homonym, which was either a cognate (e.g., novel/novela) or noncognate (e.g., fast/rápido) with Spanish. Participants showed a cost in processing when rejecting follow-up targets that were related to the contextually-irrelevant dominant meaning (e.g., BOOK for "novel"). More critically, this cost was significantly greater when the homonym was a cognate and the dominant meaning was shared with Spanish. This finding demonstrates that bilinguals activate the semantic representations of homonyms from the non-target language even in a single-language task. The critical implication for current models like the RAM is that such cross-language activation influences the strength with which a meaning competes for selection.

In the interest of extending the RAM to bilingualism one goal of the present study was to replicate the major finding from Schwartz et al (2008) and to more thoroughly examine the role that cross-language lexical activation plays in bilingual homonym processing. One limitation of the Schwartz et al (2008) study was they only implemented one SOA (250 ms). This did not allow for an analysis of how cross-language activation modulates the time-course with which meanings are activated. Thus, in the present study we included four different SOA's: 250, 500, 1250 and 2000 MS. In addition to replicating the cost in rejecting dominant meanings that are shared across languages, in Experiment 2 we also demonstrated that access to a subordinate meaning of a homonym is *facilitated* when that meaning is shared across languages. Finally, a monolingual control is included to rule out possible confounds due to stimulus characteristics.

EXPERIMENT 1

Method

Participants

176 highly proficient Spanish-English bilingual undergraduate students from the University of Texas at El Paso participated in the study. All participants earned course credit for their participation. Data from 28 participants were excluded from the analyses due to high error rates (greater than 50% on the control conditions and/or greater than 80% on the critical conditions) and one participant was excluded due to low proficiency in Spanish. These exclusions produced a final sample size of 147 participants. Participants were randomly assigned to one of the four SOA conditions (250 SOA n = 34; 500 SOA n = 46; 1250 SOA n = 33; 2000 SOA n = 34).

Materials and Design

Prime Words

The critical stimulus list included 80 English prime words. Half of these words (40) were semantically ambiguous, polarized homonyms in English that had one highly-frequent meaning. Half of these ambiguous primes (20) were English-Spanish cognates [e.g., novel (novela)] and half were noncognates [e.g., fast (rápido)]. The dominant meaning of the cognate homonyms was always shared with Spanish. Since most ambiguous words have more than two alternative meanings our selection of critical prime words was guided principally by the existence of one, clearly dominant meaning and many of the ambiguous primes had third meanings and/or senses in both English and Spanish and this was not confounded by cognate status. To minimize effects of other meanings and/or senses we made sure the dominant meaning had a published probability of at least 75% (Twilley, Dixon, Taylor, & Clark, 1994). Five Spanish-English bilingual research assistants reviewed all the selected ambiguous words and confirmed that the first two primary meanings were meanings commonly used in the surrounding bilingual community.

The remaining 40 unambiguous prime words were similarly divided into cognates [e.g., piano (piano)] and non-cognates [e.g., pencil (lápiz)]. Since homonymy is confounded with lexical frequency, cognate and non-cognate prime words were matched on lexical frequency and word length within each ambiguous condition (see Table 1).

Target words

Each prime word was paired with a target word. For each critical, ambiguous prime word the target word was related to its dominant meaning [e.g., novel (BOOK), fast (SPEED)] while for each critical, unambiguous prime word the target was completely unrelated to its meaning [e.g., piano (GRASS), pencil (HAPPY)]. It was not possible to obtain a sufficient number of target words that were all noncognates while maintaining a match in lexical characteristics and avoiding associative relationships with primes. The existence of cognate targets was not confounded by condition and a monolingual control experiment (Experiment 1B) was included to rule out effects due to such extraneous factors. An additional 80 prime-target word pairs were included for filler, “yes” trials. To ensure that the presence of a cognate or ambiguous word would not cue the participant to a “no” response, the filler primes included 30 cognates and 30 ambiguous words. Target words for these filler, “yes” primes were selected so that they were highly related to the prime word (e.g., theater-STAGE).

------ Insert Table 1 around here ------

All prime words were preceded by a sentence frame which strongly biased its meaning (subordinate meaning for ambiguous words). This sentence frame consisted of the complete sentence minus the last word. The frames were written to be as concise as possible (15 words or less) with simple syntactic structure (we avoided using embedded clauses) (see Table 2).

------ Insert Table 2 around here ------

Experiment 1 was based on a 4 X 2 X 2 mixed design. The between-subject independent variable was stimulus onset asynchrony (SOA) between the prime words and the target words (250 MS, 500 MS, 1250 MS, and 2000 MS). The two within-subject independent variables were cognate status (cognate versus non-cognate) and ambiguity (ambiguous versus unambiguous) of the critical prime words. The dependent variables were reaction time in MS measures and percent error rates on the semantic verification task.

Procedure

All interactions with participants were carried out in English (L2). After informed consent procedures, participants were tested in individual rooms and seated in front of a computer. They were instructed that they would be reading sentence frames presented on the computer screen. When they had read each frame they were to press a key on a button-box and the last word of the sentence would appear. Finally, a target word would be presented in all capital letters. They were asked to decide, as quickly and accurately as possible, whether the target word was related in meaning to the previously presented sentence. Participants were given 20 practice trials before starting the experimental trials.

Each trial was initiated by the presentation of a fixation point ("+") in the center of the screen. This fixation remained on the screen until the participant pressed a key on the response box. The sentence frame was presented until the participant made another button press. After the button press the last word of each sentence (i.e., the prime word) was presented for 250 MS. After the prime words the screen remained blank until the target word was presented in all capital letters. The latency between prime word and target word presentation depended on the SOA condition. The target word remained on the screen until the participant made a response or four seconds had elapsed. Participants completed 160 trials (80 "no" trials and 80 "yes" trials). All participants received the same experimental procedure and saw the same stimuli from the four conditions. Trials were randomly selected from each condition. After completing the computer task, participants completed a language history questionnaire in which they were asked to self-assess their proficiency in reading, writing, speaking and listening in English and Spanish on a ten-point scale. The entire experimental procedure was completed in approximately one hour.

Task Considerations

Before proceeding to a discussion of the results, we would like to address some issues related to the semantic verification task. We chose this task because it has been used previously in monolingual studies of ambiguity resolution (e.g., Gernsbacher & Faust, 1991) and we wanted a task that would require participants to explicitly select the context-appropriate meaning of the prime words. By manipulating the homonymy and cognate status of the primes rather than the targets we ensured that processing of the targets would not be further confounded by the effects that these two factors have on initial lexical access times. We want to underscore that we were interested in the time it took participants to make their semantic decision regarding the fit of the target with the preceding context. We were not interested in processes involved in the initial lexical access of the target words so we minimized any lexical differences in the targets across the four conditions.

One final concern is participants' familiarity with the subordinate meanings of our ambiguous words. First, all materials were reviewed by undergraduate research assistants from the same population as the participants. Second, unlike lexical decision, successful completion of this task requires knowledge of the subordinate meaning of the prime word. If participants were not at all familiar with the subordinate meanings of our ambiguous primes, they would have inflated error rates on the critical, "no" trials as well as the filler "yes" trials, which also included ambiguous primes. Third, if participants did not truly know the subordinate meaning of the primes this would work against our hypotheses and increase the probability of making a Type II error.

Results and Discussion

Language history questionnaire data

The data from the language history questionnaires are summarized in Table 3. Participants reported acquiring Spanish earlier (2.5 years of age) than English (5.8 years of age), [t_1 (102) =7.3, p < .01]. Within the context of this study we use the labels “L1” and “L2” according to the relative timing of acquisition. Thus, the language acquired earlier is designated as L1 and L2 refers to the language acquired later on in life. Since participants in the present experiment acquired English somewhat later in life, around six years of age, it is considered to be the L2. There were no significant differences between participants’ mean English proficiency or Spanish proficiency ratings across the four SOA conditions (all p’s < .05).

------ Insert Table 3 around here ------

Overall, participants rated their proficiency high in both Spanish (8.2) and English (9.1) (on a scale of 1 to 10). However, they consistently rated their English skills higher than their Spanish skills, [t_1 (146) = 4.5, $p < .05$], suggesting that they had become more dominant in their L2. This shift in language dominance from the L1 to the L2 is commonly observed at the University since most of the students complete their academic work in their L2. Participants also reported frequent and daily use of both of their languages.

Error rate and reaction time analyses

Mean RTs for each participant for correct trials were calculated. RTs that were faster than 500 MS were counted as outliers and excluded from the analyses. Any participant who had a greater than 50% error rate on the completely unrelated trials was excluded. Furthermore, any participant who had a greater than 80% error rate on the critical ambiguous conditions was also excluded. We raised the criterion for the critical ambiguous conditions, since we would expect greater error rates due to our manipulation (forcing participants to reject targets related to a dominant meaning of an ambiguous word).

Error rate analyses

Overall participants made significantly more errors on "yes" trials than on completely unrelated, control "no" trials (25.6% and 9.7% respectively), [t_1 (146) = 12.1, p <.05]. This is likely due in part to the difficulty in rejecting target words that were related to the dominant meaning of the ambiguous primes on "no" trials (e.g., rejecting "SPEED" after seeing "fast"). This difficulty raised the participants' criterion for a "yes" response, thus producing a higher rate of incorrect rejections.

Statements of significance in this paper for critical analyses are based on F_1 (or t_1) analyses, treating participants as a random factor since critical and control items were not randomly selected, rather they were matched for word frequency and length, on an item-by-item basis, making F_{min} and F_2 too conservative as statistical tests of significance (see Raaijmakers, 2003 and Raaijmakers Schrijnemakers, and Gremmen, 1999). However, F_2 and F_{min} values are provided for reference.

A three-way (SOA x ambiguity x cognate status) repeated measures ANOVA was performed on the participants' mean percent error rates for the critical "no" trials. The main effect of SOA was not significant [F_1 (3, 143) = 1.5 MSE = 439.6, p > .05; F_2 (3, 114) = 30.9 MSE = 26.7, p < .05; F_{min} (1, 159) = 1.5, p = 0.22]. The main effect of ambiguity was significant [F_1 (1, 143) = 138.0 MSE = 182.4, p < .05; F_2 (1, 38) = 32.1 MSE = 454.6, p < .05; F_{min} (1, 72) = 26.1, p <.001]; reflecting the higher error rates for trials in which the prime was ambiguous versus unambiguous. Most critically, the main effect of ambiguity interacted significantly with cognate status [F_1 (1, 143) = 36.9 MSE = 53.4, p < .05; F_2 (1, 38) = 2.1 MSE = 656.1, p > .05; F_{min} (1, 44) = 2.0, p = .17]. This interaction reflected the fact that, for the ambiguous conditions, there was an increase in error rates when the primes were also cognates. In other words, participants had more difficulty rejecting a target word related to the contextually-irrelevant, dominant meaning of an ambiguous prime if it was shared with Spanish. This finding supports our hypothesis that, when the meaning of an ambiguous word is shared across a bilingual's two languages, it is more strongly activated than a language-exclusive meaning.

The three-way interaction with SOA did not reach statistical significance [F_1 (1, 143) = 1.4 MSE = 53.4, p > .05; F_2 (1, 38) = 2.0 MSE = 24.3, p = .12; F_{min} (1, 170) = 0.8, p = .37]. Given the theoretical importance of understanding the dynamics of activation across SOA's and the fact that the three-way interaction approached significance in the analysis by items, a follow-up 2 (SOA) X 2 (ambiguity) X 2(cognate status) ANOVA was performed on the mean percent error rates at the 500 and 1250 SOA's. The three-way interaction approached significance [F_1 (1, 79) = 3.5 MSE = 56.7, p = .06; F_2 (1, 38) = 1.3 MSE = 24.1, p < .05; F_{min} (1, 116) = 0.9, p = .33. Examination of Figure 1 reveals a pattern suggestive of a contrast in the temporal dynamics of cross-language versus within-language ambiguity resolution. More specifically, the trend line for the ambiguous noncognate condition shows a gradual, practically-linear drop in error rates across increasing SOA's. In contrast, the line for the ambiguous cognates shows a sudden peak in error rates at the 1250 SOA which then declines by 2000 MS. Even more interestingly, this peak is coupled with a similar but attenuated peak for the unambiguous cognate condition. The simultaneity of these peaks for both cognate conditions (ambiguous and unambiguous) suggests that at the 1250 SOA activation of lexical representations from the non-target language is at its height, rendering enhanced interference for ambiguous cognates and facilitation for unambiguous cognates. Although the post-hoc analysis provides some support for a peak in cross-language interactivity at the 1250 SOA we need to be cautious in our interpretation.

Reaction time analyses

Analyses on decision latency data was performed for correct trials only. Overall the mean decision latencies for "yes" (1363MS) and "no" trials (1393 MS) did not differ significantly [t_1 (146) = 1.1, p >.05]. The main effect of SOA was significant [F_1 (3, 143) = 5.0 MSE = 567,322.5, p < .05; F_2 (3, 114) = 97.0 MSE = 16,236.7, p< .05; F_{min} (1, 151) = 4.7, p = 0.03]; reflecting a decrease in RT from the 250 to the 1250 SOA. The main effect of ambiguity was significant [F_1 (1, 143) = 34.9 MSE = 40,028.7, p < .05; F_2 (1, 38) = 10.2 MSE = 86,873.8, p < .05; F_{min} (1, 77) = 7.9, p =.006]; reflecting the slower reaction times for trials in which the prime was ambiguous versus unambiguous. The main effect of cognate status was significant [F_1 (1, 143) = 13.4 MSE = 18545.2, p < .05; F_2 (1, 38) = 0.7 MSE = 73486.6, p > .05; F_{min} (1, 59) = 0.7, p =.42]; reflecting faster reaction times for cognate conditions relative to noncognate conditions. The main effect of cognate status was qualified by a significant interaction with SOA [F_1 (1, 143) = 3.0 MSE = 18545.2, p < .05; F_2 (3, 114) = 1.2 MSE = 16236.6, p > .05; F_{min} (1, 129) = 0.9, p =.35]; reflecting the larger magnitude of cognate facilitation in response time at the earliest SOA. The critical interaction between cognate status and ambiguity approached significance [F_1 (1, 143) = 2.8 MSE = 23,037.9, p = .09; F_2 (1, 38) = 2.6 MSE = 73486.6, p > .05; F_{min} (1, 64) = 1.4, p = .25]. This reflected the trend in a decrease in cognate facilitation for ambiguous conditions (a difference of 20 MS) relative to unambiguous conditions (a difference of 63 MS). In other words, when primes were ambiguous, competition from the shared, dominant meaning decreased the cognate facilitation in response time. An examination of Figure 2 reveals that the cognate facilitation in response time was restricted to the 250 SOA. At the longest SOA (2000 MS) this facilitation actually reversed for the ambiguous cognate condition. In terms of further contrasting the time-course of cross-language versus within-language ambiguity; by the latest S0A the cost associated with ambiguity for the noncognate conditions disappeared [t_1 (33) = 0.05, $p > .05$; t_2 (38) = 0.5, $p > .05$] . However, for the cognate conditions this difference still persisted [t_1 (33) = 2.1, $p < .05$; t_2 (38) = 2.1, $p < .05$] thus suggesting that the cross-language ambiguity still had not been fully resolved. This provides converging evidence with the error rate data that the coactivation of the shared, dominant meaning of the cognates produced additional competition during processing.

Overall the results from Experiment 1 provide evidence that bilingual lexical disambiguation is affected by the coactivation of meanings from the non-target languages. To confirm that the observed results were indeed due to the cognate status of the materials and the bilingualism of the participants, a monolingual control experiment was conducted.

EXPERIMENT 1B: MONOLINGUAL CONTROL

Method

Participants

Forty-four undergraduate students who were not proficient in Spanish from both The University of Texas at El Paso (n = 21) and The Pennsylvania State University (n = 24) participated in the study. All participants earned course credit for their participation. Data from 5 participants were excluded from the analyses using the same performance criteria as Experiment 1, producing a final sample size of 40. Participants were randomly assigned to two SOA conditions (250 SOA n = 20; 1250 SOA n = 20).

Materials and Design

The same materials and design as Experiment 1A was used.

Procedure

The same procedure as Experiment 1A was conducted

Results and Discussion

Language history questionnaire data

All participants reported English as their native language. Five participants reported proficiency in another language other than English (German, Arabic, Polish, Tagalog, Yoruba). Participants reported some exposure to Spanish, primarily through high school courses. Participants recruited from the El Paso area reported being exposed to Spanish in their community, through hearing conversations and exposure to media. However, none of these participants reported regular use of Spanish. Overall, their self-assessed proficiency ratings for Spanish were at floor (M = 1.4) while their ratings for English were at ceiling (M = 9.5).

Error rate and reaction time analyses

A three-way (SOA x ambiguity x cognate status) repeated measures ANOVA was performed on the participants' mean percent error rates for the critical "no" trials. Only the main effect of ambiguity was significant [F_1 (1, 38) = 22.3 MSE = 665.9, $p > .05$], reflecting higher error rates for trials with ambiguous primes relative to unambiguous primes. No other main effects or interactions were significant (all p values > .05).

A three-way (SOA x ambiguity x cognate status) repeated measures ANOVA was performed on the reaction times of correct trials. The main effect of ambiguity was significant [F_1 (1, 38) = 3.6 MSE = 79,540.7, $p > .05$], reflecting longer response times for trials with ambiguous primes relative to unambiguous primes. No other main effects or interactions were significant (all p values > .05).

In summary, participants who were not proficient in Spanish did not show any effects of the cognate status of the critical items. This helps ensure that the observed findings from Experiment 1 were not due to some confounding in the materials. In the next experiment we further examined the coactivation of shared meanings for ambiguous words across languages. However, this time we tested whether coactivation of a shared, subordinate meaning would *facilitate* access to that meaning in a paradigm requiring its maintained activation in the face of competition from the dominant meaning.

EXPERIMENT 2

Method

Participants

Originally 241 Spanish-English bilinguals participated in this study. However, due to the high level of difficulty of the task 107 participants were excluded from the analyses because they did not reach performance accuracy criterion on ambiguous trials (achieving a minimum of 80% accuracy on trials with ambiguous primes). An additional 8 participants were excluded because they did not meet the performance criterion of 50% accuracy or better on control trials. This left a final sample size of 125.

Participants were randomly assigned to one of the four SOA conditions (250 SOA n = 36; 500 SOA n = 35; 1250 SOA n = 24; 2000 SOA n = 38).

Materials and Design

Prime Words

The critical stimulus list included 152 English prime words. Seventy-six of these were semantically ambiguous, polarized homonyms in English that had one highly-frequent meaning. Half of these ambiguous primes (38) were English-Spanish cognates [e.g., arm (arma)] and half were noncognates [e.g., ball (pelota)]. As with Experiment 1, our selection of critical prime words was guided principally by the existence of one, clearly dominant meaning. For the ambiguous cognate condition we selected those for which the subordinate meaning was shared with Spanish and the dominant meaning was not. To minimize effects of other meanings and/or senses we made sure the dominant meaning had a published probability of at least 75% (Twilley et al., 1994). Once again bilingual research assistants from the surrounding community verified that both the dominant and subordinate meanings were commonly known and used in the region. The remaining 76 prime words were unambiguous words and were similarly divided into cognates (n = 38) [e.g., piano (piano)] and non-cognates (n =38) [e.g., pencil (lápiz)]. As in Experiment 1 cognate and non-cognate prime words were matched on lexical frequency and word length within each ambiguous condition (see Table 4).

Target words

Each prime word was paired with a target word. For each critical, ambiguous prime word the target word was related to its subordinate meaning (e.g., plane- FLAT; ruler- KING) and each critical, unambiguous prime word was paired with a target related to its meaning (e.g., guitar- BASS; carrot- CELERY].

------ Insert Table 4 around here ------

The entire set of critical prime-target word pairs were randomly split into two experimental running lists (n = 76). Additional filler, “no” pairs (n = 76) were included in each running list. To ensure that the presence of a cognate or ambiguous word would not cue the participant to a “yes” response, the primes of these filler pairs included 30 cognates and 30 ambiguous words. Target words for these filler, “no” trials were unrelated to the prime words (e.g., word-TIGHT).

All prime words were preceded by a sentence frame which strongly biased its meaning (dominant meaning for ambiguous words). This sentence frame consisted of the complete sentence minus the last word. The frames were written to be as concise as possible (15 words or less) with simple syntactic structure (we avoided using embedded clauses) (see Table 5).

------ Insert Table 5 around here ------

Experiment 2 was based on a 4 X 2 X 2 mixed design. The between-subject independent variable was stimulus onset asynchrony (SOA) between the prime words and the target words (250 MS, 500 MS, 1250 MS, and 2000 MS). The two within-subject independent variables were cognate status (cognate versus noncognate) and ambiguity (ambiguous versus unambiguous) of the critical prime words. The dependent variables were reaction time in MS measures and percent error rates on the semantic verification task.

Procedure

The experimental procedure was identical to Experiment 1, except this time participants were instructed to respond “yes” to target words related to *any* meaning of the last word of each sentence.

Results and Discussion

Language history questionnaire data

The data from the language history questionnaires are summarized in Table 6. Similar to Experiment 1, participants reported acquiring Spanish earlier (3.2 years of age) than English (4.9 years of age), [t_1 (116[1]) = 3.5, p < .05]. There were no significant differences between participants’ mean English proficiency or Spanish proficiency ratings across the three SOA conditions (all p’s < .05). Participants rated their proficiency high in both Spanish (8.0) and English (9.1) but consistently rated their English skills higher, [t_1 (124) = 5.8, p < .05], reflecting a similar shift in dominance as that observed in Experiment 1. Participants also reported frequent and daily use of both of their languages.

Error rate analyses

[1] The reduced degree of freedom is due to some participants not responding to this item on the questionnaire

Participants made significantly more errors on “no” trials than on completely unrelated “yes” trials (17.4% and 13.3% respectively), [t_1 (125) = 2.9, p <.05].

A three-way (SOA x ambiguity x cognate status) repeated measures ANOVA was performed on the participants’ mean percent error rates for the critical “yes” trials. The main effect of SOA was not significant [F_1 (3, 121) = 0.03 MSE = 670.0, p > .05; F_2 (3, 198) = 19.7 MSE = 81.3 p< .05; F_{min} (1, 286) = .03, p = .86]. The main effect of ambiguity was significant [F_1 (1, 121) = 349.5 MSE = 344.1, p < .05; F_2 (1, 66) = 133.3 MSE = 1004.8, p< .05; F_{min} (1, 112) = 96.5, p <.05]; reflecting the higher error rates for trials in which the prime was ambiguous versus unambiguous. Most critically, the main effect of ambiguity interacted significantly with cognate status [F_1 (1, 121) = 14.3 MSE = 79.0, p < .05; F_2 (1, 66) = 2.1 MSE = 687.2, p> .05; F_{min} (1, 81) = 1.8, p = .18]. This interaction reflected the fact that, for the ambiguous conditions, there was a decrease in error rates when the primes were also cognates. In other words, participants were better able to accept a target word as being related to the subordinate meaning of the prime word when this was a cognate and the meaning was shared across the two languages.

The three-way interaction with SOA just reached statistical significance [F_1 (3, 121) = 2.6 MSE = 79.0, p = .05; F_2 (3, 198) = 2.4 MSE = 80.3, p = .07; F_{min} (1, 302) = 1.2, p = .27]. An examination of Figure 3 reveals that the accuracy advantage for the ambiguous cognate primes was maintained up until the 1250 ms SOA. At that SOA the error rates for the ambiguous noncognates dropped down to the level of the cognates. Indeed, follow up t-tests revealed that at the 500 ms SOA the cognate advantage was statistically reliable [t_1 (33) = 2.9, p <.05; t_2 (29) = 1.9, p = .07], whereas at the 1250 ms SOA it no longer was [t_1 (22) = .85, p >.05; t_2 (29) = .63, p >.0]. This suggests that at the 1250 ms SOA activation of the subordinate meaning of the noncognates reached a sufficient level for it to be as readily accessed as the shared subordinate meanings of the cognates.

Reaction time analyses

Analyses on decision latency data was performed for correct trials only. Overall the mean decision latencies for "yes" trials (1303.9 MS) were significantly faster than for "no" trials (1855.0 MS) [t_1 (133) = 15.2, p <.05]. The main effect of SOA was significant [F_1 (3, 121) = 2.8 MSE = 395,640, p < .05; F_2 (3, 198) = 56.2 MSE = 139197.5, p< .05; F_{min} (1, 206) = 2.7, p = .10]; reflecting a particularly sharp decrease in RT at the 1250 SOA (see Figure 4). The main effect of ambiguity was significant [F_1 (1, 121) = 340.4 MSE = 73,148.8, p < .05; F_2 (1, 66) = 71.1 MSE = 45,368.8, p < .05; F_{min} (1, 88) = 58.8, p < .05.]; reflecting the slower reaction times for trials in which the prime was ambiguous versus unambiguous. The critical interaction between cognate status and ambiguity was significant [F_1 (1, 121) = 6.7 MSE = 60,995.1, p < .05; F_2 (1, 66) = 1.2 MSE =297,344.9, p > .05; F_{min} (1, 94) = 1.0, p = .32]. However, this time the interaction was due to *slower* responding to trials with cognate primes for the *un*ambiguous conditions only.

Examination of Figure 4 reveals that this counterintuitive pattern was largely restricted to the 1250 MS SOA. This was the SOA in which response times overall were most speeded. One interpretation is that, reaction times to trials with control primes were particularly fast because these primes were completely unambiguous. Even semantically-unambiguous cognates are ambiguous at the language level and this might have produced slightly slower responding relative to completely unambiguous, control words. Further examination of Figure 4 suggests that the expected interaction, driven by cognate facilitation for ambiguous trials, did not occur until the 2000 MS SOA. This was confirmed by a post-hoc ANOVA, [F_1 (1, 34) = 6.8 MSE = 54,189.5, $p < .05$; F_2 (1, 66) = 2.2 MSE = 950,089.4, $p > .05$; F_{min} (1, 81) = 1.7, $p = .20$]

In summary, the findings from Experiment 2 provide further evidence, convergent with Experiment 1, that access to meanings of ambiguous words is further influenced by cross-language, non-selective activation. At the earlier SOA's (250 and 500) participants were more accurate in correctly accepting a target word as being related to the subordinate meaning of a preceding ambiguous cognate prime. By the 1250 SOA this advantage was eliminated. In terms of reaction times, the cognate benefit for accessing subordinate meanings was not observed until the latest, 2000 SOA. In the following discussion we interpret this pattern along with that observed in Experiment 1 in terms of both the reordered access model of lexical disambiguation and in terms of monolingual and bilingual theories of lexical disambiguation.

GENERAL DISCUSSION

Convergence with existing theories

The primary objective of the present study was to examine whether cross-language lexical activation influences L2 lexical disambiguation processes for bilinguals. We predicted that when bilinguals confront ambiguous L2 words that are cognates with the L1, coactivation of the L1 representation would influence the time-course and strength with which individual meanings would be activated. The findings across Experiments 1 and 2 confirm this. Across both experiments, processing of target words was influenced by whether it was related to a shared, cognate meaning with Spanish. In Experiment 1 there was boosted competition from the coactivated dominant meaning of ambiguous cognate prime words (e.g., novel). Consequently participants made significantly more errors on trials that required them to maintain activation of subordinate meanings while rejecting targets related to dominant meanings. Experiment 2 served as the perfect mirror image of Experiment 1. In that case, coactivation of shared, subordinate meanings facilitated activation of those meanings in the face of competition from the contextually-supported dominant meanings. Thus, the bilinguals in the present study non-selectively accessed both meanings of the biased ambiguous prime words. This converges with previous research demonstrating that highly-proficient bilinguals can quickly activate the multiple meanings of ambiguous words in ways similar to native speakers (Frenck-Mestre & Prince, 1997).

The incorporation of different SOA's in the present study allowed us to examine the time frame with which the meanings of the homonyms remained active and how this differed as a function of cognate status. The observed pattern can be incorporated into the three phase model of L2 ambiguity resolution (Elston-Güttler & Friederici, 2007; Elston-Güttler & Friederici, 2005). Phase 1 of this model refers to early lexical spreading activation. Due to the language non-selective nature of bilingual lexical processing, this activation would spread across both languages. Consequently there would be a significant boost in activation for meanings shared across both languages. This was evident in the present study, in which the shared dominant and subordinate meanings showed high levels of activation at the earliest SOA. The effect of this boosted activation was particularly clear for the shared, subordinate meanings which showed an accuracy advantage relative to non-shared meanings right from the start.

The second phase of this model refers to the integration of meanings of homonyms into sentential context. This can be conceptualized as the more cognitively-taxing phase, and it is the phase in which bilinguals and monolinguals differ the most. Once again, findings from the present study converge with this assumption. In Experiment 1 the cost of ambiguity for the cognates was markedly greater than the non-cognates at the 1250 ms SOA. This cost was reflective of the added difficulty of integrating a subordinate meaning in the face of competition from a shared, dominant meaning. In Experiment 2 the 1250 ms SOA was marked by the elimination of a cognate advantage in error rates.

By this time-frame, the target word had been integrated with the subordinate meanings of both the cognate and noncognate ambiguous prime words (recall that in this experiment the task was to integrate to the prime word, rather than the sentence).

The third phase of the model refers to the completion of disambiguation, in which processing of non-natives and natives once more converges. In the present study the error rates for the ambiguous cognates and noncognates across both experiments began to converge at the latest SOA. However, it is interesting to note that across both experiments there still remained a substantial cost associated with ambiguity, even at the 2000 ms SOA. This was likely due to the difficulty of the semantic verification task. In both experiments this task required participants to reject dominant meanings that were either supported by the target word (Experiment 1) or sentential context (Experiment 2).

The nature of the general time-course of lexical disambiguation in the present study is further highlighted by the divergent pattern observed in the reaction time versus error rate data. Across both experiments the latency data showed minimal differences between the ambiguous cognate and non-cognate conditions. For example, in Experiment 1 the latency data at the earliest SOA's showed a general cognate advantage and in Experiment 2 latency differences between the ambiguous cognate and non-cognate conditions did not emerge until the 2000 ms SOA. This divergence can be understood through the two-process theory of context effects on lexical activation (Stanovich & West, 1981).

According to this theory, context influences word identification by a combination of fast-acting, automatic processes (i.e. spreading activation) that produce early facilitative effects, and slower-acting, conscious- attentional processes that produce later inhibitory effects. Reaction times more generally tap into the fast-acting, automatic processes. Thus, in Experiment 1, general cognate facilitation was observed at the earlier SOA's, which turned into inhibition for the ambiguous conditions only at the latest SOA. The error rates, on the other hand, were tapping into the slower, more conscious-driven processes of lexical disambiguation and this is why these generally reflected inhibitory effects. In Experiment 1 the differences in accuracy were driven by higher error rates for the ambiguous cognate conditions. In Experiment 2 the differences were due to higher error rates for the ambiguous non-cognate conditions at the earlier SOA's (the error rates for the ambiguous cognates remained level throughout the SOA's). Together, these patterns suggest that resolving competition from a dominant meaning, whether it be instantiated by a target word (Experiment 1) or a preceding sentence (Experiment 2) is a slower-firing, more consciously driven process.

The pattern of findings for the non-cognate conditions are compatible with the reordered access model (RAM) which makes the following assumptions: (1) All meanings of a homonym are exhaustively accessed, (2) The timing of this access depends largely on the relative frequency of the meaning, however, (3) the presence of a biasing context can change the relative ordering of activation. Across both experiments there was a significant cost associated with activation of the subordinate meanings of the non-cognate ambiguous primes, even when it was supported by a preceding sentential context, as in Experiment 1. The RAM accounts for this, first by assuming that the decreased frequency of subordinate meanings prevents them from being quickly activated. Second, although the contextual support of a subordinate meaning allows it to be activated at an earlier time-frame, exhaustive access of the dominant meaning forces competition between the two.

Expanding existing theories

While findings from the non-cognate conditions support the RAM in its current form, findings from the cognate conditions extend it. In the present study we observed both greater competitive (Experiment 1) and facilitative (Experiment 2) effects for shared, cognate meanings. One option is to assume that the relative frequency differences between the subordinate and dominant meanings are simply altered for cognates due to increased exposure. In this case, we would be stating that ambiguous cognates that have shared dominant meanings across languages are simply more biased or polarized while ambiguous cognates for which the subordinate meaning is shared are simply less polarized and thus more balanced. However, the ambiguous cognate stimuli used in the present study were not lexically identical across languages, making it unlikely that participants were activating a single, language-general representation. Also, the ambiguous cognates and noncognates were matched in terms of the relative frequency of the dominant meaning as provided by existing English norms. Furthermore, we recently completed an off-line norming study of the ambiguous cognates with bilinguals drawn from the same population as the present study (Arêas da Luz Fontes & Schwartz, submitted). Preliminary analyses suggest that the bilinguals provided the dominant meaning with a similar likelihood as the participants from the monolingual norms. This makes it less likely that the relative dominance of the primary meanings of the ambiguous cognates could have been significantly greater than those of the non-cognates.

Based on the reasoning above, we conclude that the greater magnitude in both inhibitory and facilitative effects were due to cross-language lexical activation of the L1 representations. This coactivation altered the time-course and strength with which these meaning became activated. The effect on time-course was particularly evident in the pattern of error-rates across the two experiments. In Experiment 1 the coactivated dominant meaning produced a spike in error rates at the 1250 ms SOA while the error rates for the ambiguous noncognate conditions showed a simple, consistent decline across all of the SOA's. This suggests that the coactivated dominant meaning remained activated for a longer period of time. In Experiment 2 the accuracy advantage for the ambiguous cognate conditions was observed up until the 1250 ms SOA. At that point activation of the subordinate meaning of the noncognate ambiguous words was strong enough to bring error rates down to the same level. This suggests that the coactivated subordinate meaning was activated during an earlier time-course relative to that of the non-cognate.

We are proposing a bilingual version of the RAM (B-RAM) that incorporates cross-language lexical activation as an additional factor that influences the relative time-line with which various meanings become activated and compete. This factor is separable from influences due to differences in meaning frequency that occur through extended language use. Future research can further dissociate the differential contribution of relative meaning frequency and cross-language activation by including language-blocking versus language-mixing manipulations as well as the lexical form overlap of the critical word stimuli.

The present study adds to existing theories and models of homonym processing by comparing disambiguation of words that are ambiguous within a language with those that are ambiguous across languages. Future studies should examine the time-line of the disambiguation of cognates and non-cognates more precisely through methods such as eye-movement monitoring and the use of ERP's. Future research should also examine the extent to which cross-language lexical activation can completely reorder the time-line with which subordinate and dominant meanings are activated. One possibility is that cross-language lexical activation can override any ordering effects based on relative frequency differences. For example, when a subordinate meaning is shared across languages it is activated early enough to compete with the dominant meaning, even in the absence of strong contextual support.

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Table 1

Lexical characteristics of prime-target stimuli of Experiment 1

	Condition			
	Ambiguous Primes		Unambiguous Primes	
	Cognate	Noncognate	Cognate	Noncognate
Example Pair	novel- BOOK	drag- PULL	poet- BUILD	happy- BEAUTY
Mean Prime Frequency[1]	113.8	95.9	70.2	101.1
Mean Prime Length[2]	5.1	5.0	5.9	6.0
Mean Target Frequency[1]	98.0	115.5	97.1	115.1
Mean Target Length[2]	5.5	5.0	5.0	5.1

[1.] Celex
[2.] Number of letters

Table 2

Example materials of sentences, prime and target words by conditions

Prime condition	Sentences	Prime	Target
Ambiguous cognate	He is an original thinker and all of his ideas are	novel	BOOK
Ambiguous non-cognate	Before tossing the cigarette she took one more	drag	PULL
Unambiguous cognate	Though he sometimes wrote prose, he was also a	poet	BUILD
Unambiguous non-cognate	She was tired of feeling depressed and made an effort to feel	happy	WOOD

Table 3

Age of acquisition and self-assessed proficiency ratings of the Spanish-English bilingual participants of Experiment 1 (n=147)

Age of Acquisition (years)		
Spanish (L1)	2.5	
English (L2)	5.8	
Self-Reported Ratings[1]		
Skill	Spanish (L1)	English (L2)
Reading	8.0	9.1
Writing	7.4	8.9
Speaking	8.5	9.0
Listening	8.9	9.3
Mean rating	**8.2**	**9.1**

1. Based on a scale of one to ten.

Table 4

Lexical characteristics of the four critical prime conditions of Experiment 2

	Condition			
	Ambiguous Primes		Unambiguous Primes	
	Cognate	Noncognate	Cognate	Noncognate
Example Pair	plane- FLAT	ruler- KING	guitar- BASS	carrot- CELERY
Mean Prime Frequency[1]	69.1	76.2	58.0	71.8
Mean Prime Length[2]	5.6	5.2	6.0	6.4
Mean Target Frequency[1]	119.2	79.3	63.2	150.5
Mean Target Length[2]	6.3	5.8	6.2	5.8

1. Celex
2. Number of letters

Table 5

Example materials of sentences, prime and target words for Experiment 2

Prime condition	Sentences	Prime	Target
Ambiguous cognate	He trained for months before entering the	race	ETHNICITY
Ambiguous non-cognate	Drawing a straight line is easier with a	ruler	KING
Unambiguous cognate	The drummer of the band could also sing and play the	guitar	BASS
Unambiguous non-cognate	When she wanted to give her rabbit a treat she would offer a	carrot	CELERY

Table 6

Age of acquisition and self-assessed proficiency ratings of the Spanish-English bilingual participants of Experiment 2 (n=125)

Age of Acquisition (years)		
Spanish (L1)	3.2	
English (L2)	4.9	
Self-Reported Ratings[1]		
Skill	Spanish (L1)	English (L2)
Reading	7.9	9.1
Writing	7.2	8.9
Speaking	8.1	9.0
Listening	8.7	9.3
Mean rating	**8.0**	**9.1**

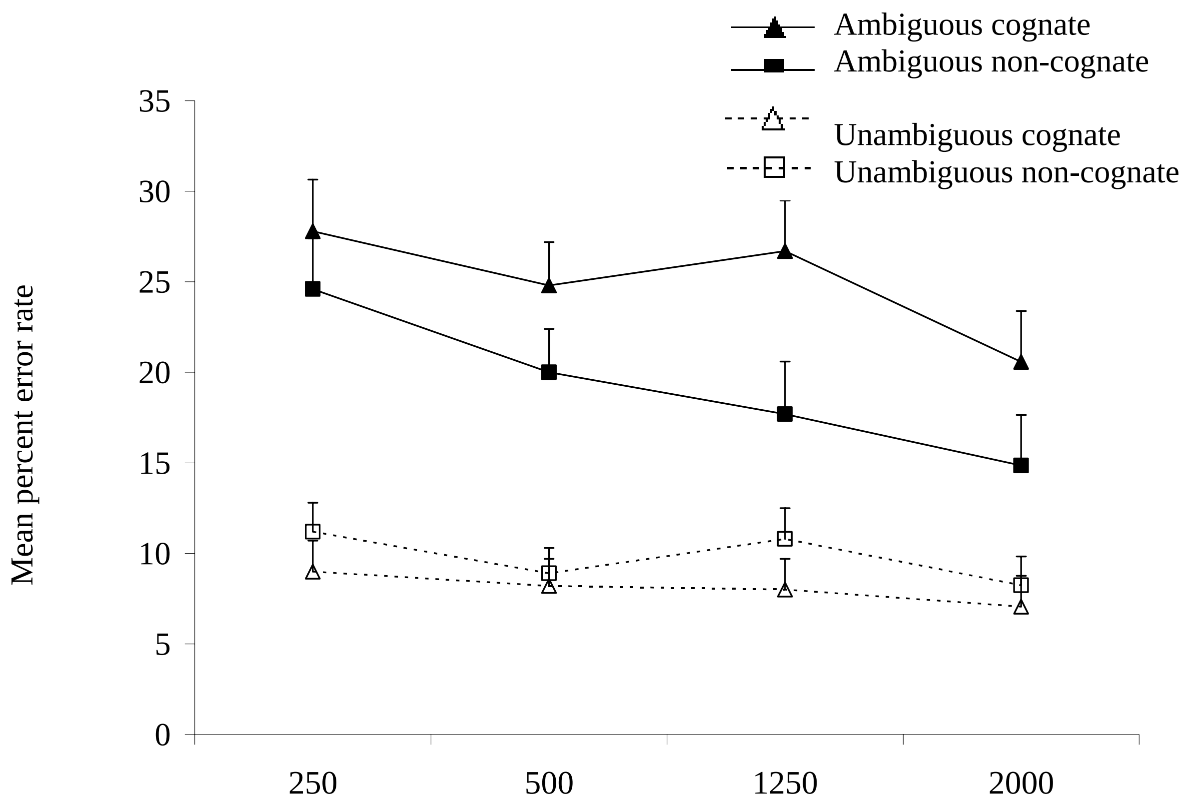
1. Based on a scale of one to ten.

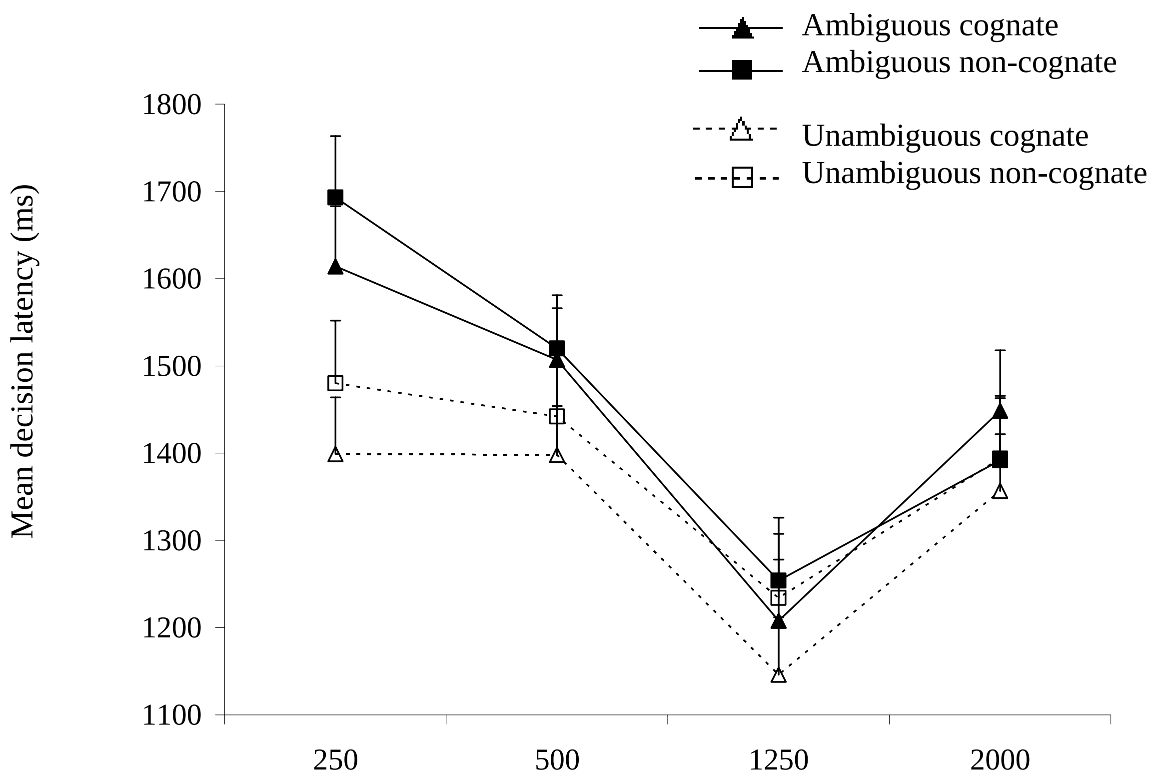
Figure 1. Mean percent error rates of Experiment 1 for the four critical conditions across SOA conditions

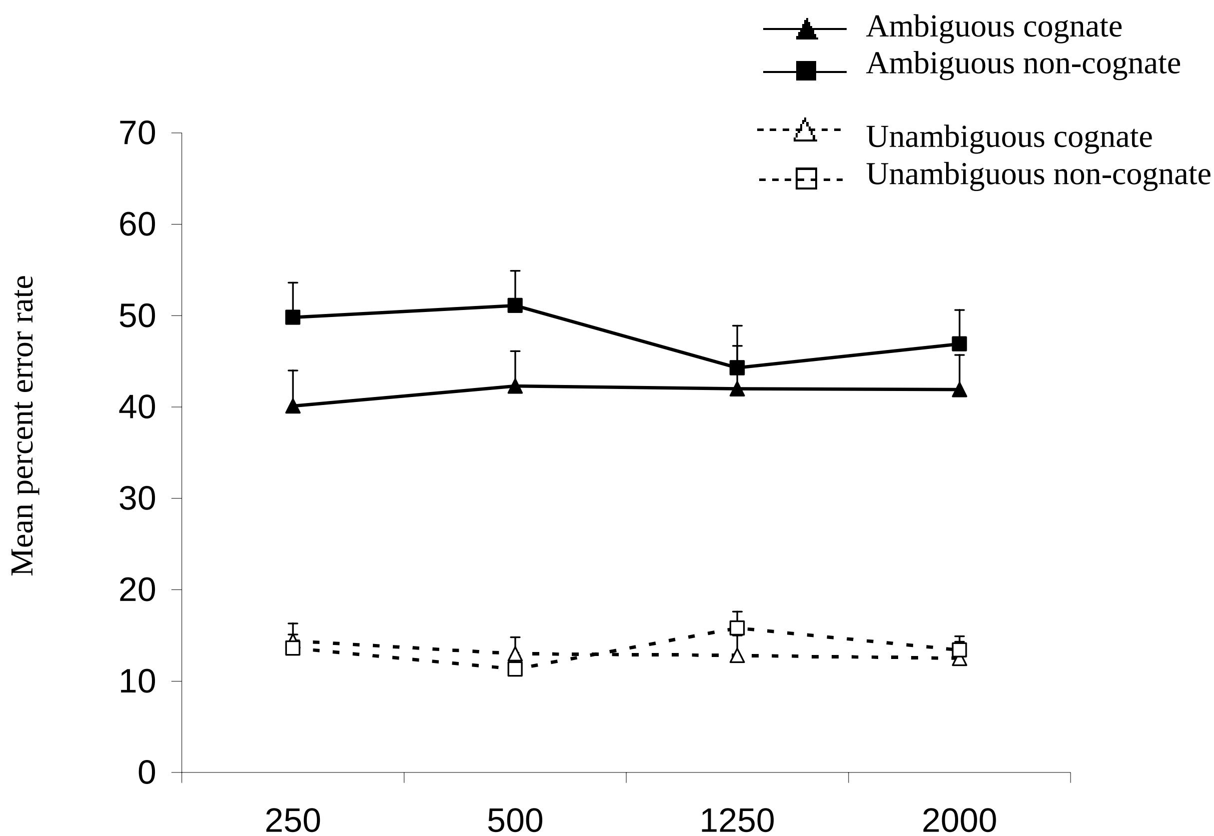
Figure 2. Figure 1. Mean decision latencies of Experiment 1 for the four critical conditions across SOA conditions

Figure 3. Mean percent error rates of Experiment 2 for the four critical conditions across SOA conditions

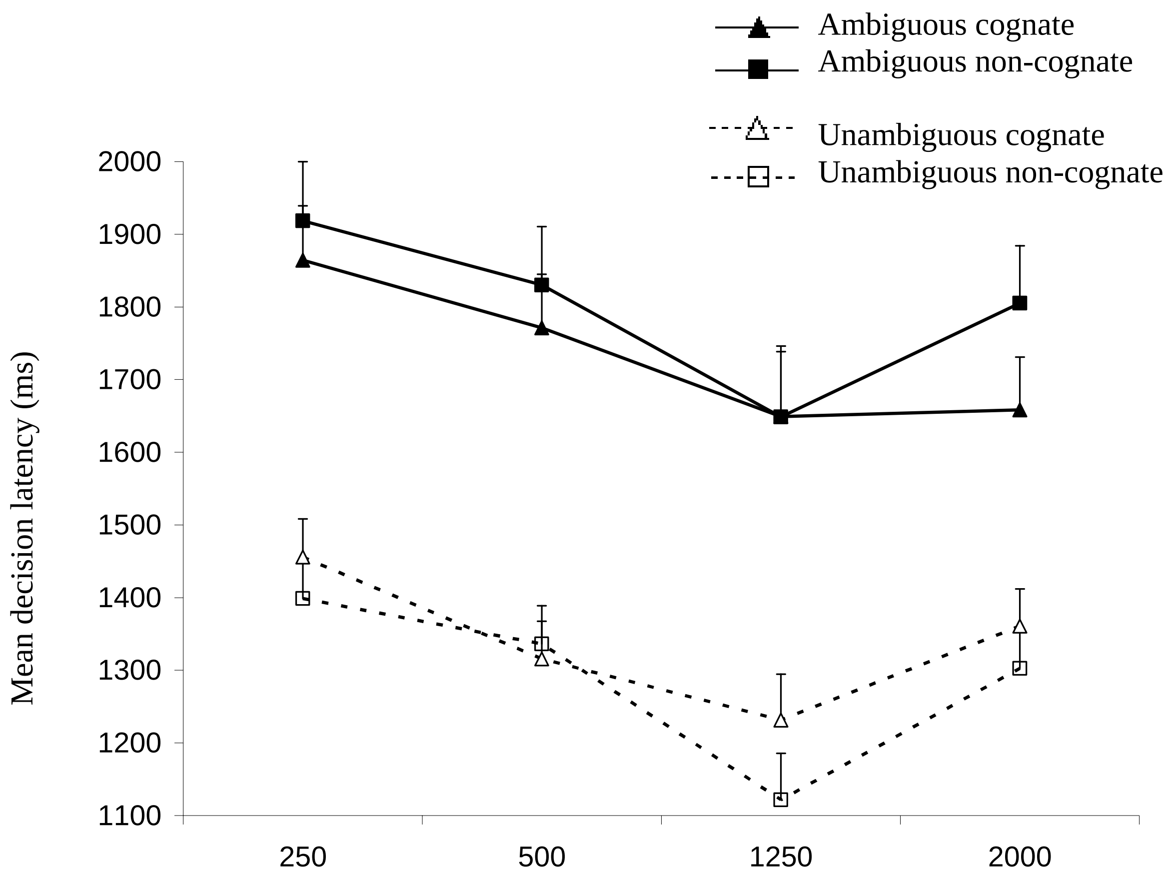
Figure 4. Mean decision latencies of Experiment 2 for the four critical conditions across SOA conditions


Ambiguous cognate
Ambiguous non-cognate
Unambiguous cognate
Unambiguous non-cognate
Mean percent error rate
35
30
25
20
15
10
5
0
250
500
1250
2000


Ambiguous cognate
Ambiguous non-cognate
Unambiguous cognate
Unambiguous non-cognate
Mean decision latency (ms)
1800
1700
1600
1500
1400
1300
1200
1100
250
500
1250
2000



Ambiguous cognate
Ambiguous non-cognate
Unambiguous cognate
Unambiguous non-cognate
Mean percent error rate
70
60
50
40
30
20
10
0
250
500
1250
2000



Ambiguous cognate
Ambiguous non-cognate
Unambiguous cognate
Unambiguous non-cognate
Mean decision latency (ms)
2000
1900
1800
1700
1600
1500
1400
1300
1200
1100
250
500
1250
2000