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Within- and Between-Language Priming Differ: Evidence From Repetition of Pictures in Spanish–English Bilinguals

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In the current study, the authors used an immediate repetition paradigm with pictures to observe whether repetition enhances word production in bilinguals. In Experiment 1, participants were asked to name pictures that were named previously in the same language (Spanish–Spanish or English–English) or in the opposite language (Spanish–English or English–Spanish). Results revealed a repetition effect both within languages and between languages. Furthermore, there was an asymmetry within language, with repetition priming being larger in Spanish than in English. Experiment 2 and 3 revealed that lag interacted with language for both within- and between-language priming. However, lag resulted in a decrease in the asymmetry for within- but not between-language priming. The results are consistent with the view that within- and between-language repetition priming are mediated by different mechanisms.

One of the central questions in bilingual language processing centers on how information crosses from one language to the other. A number of paradigms have been used to address this issue. This includes translation (de Groot, Dannenburg, & Van Hell, 1994; Sholl, Sankaranarayanan, & Kroll, 1995; Snodgrass, 1993), semantic priming (Altarriba, 1991; Grainger & Beauvillain, 1988; Grainger & O'Regan, 1992; Hernandez, Bates, & Avila, 1996; Keatley & de Gelder, 1992; Keatley, Spinks, & de Gelder, 1994; Tzelgov & Eben-Ezra, 1992), and repetition priming (Kirsner, Brown, Abrol, Chadha, & Sharma, 1980; Monsell, Matthews, & Miller, 1992). There is evidence that cross-language semantic priming disappears under certain conditions whereas within-language semantic priming does not (Grainger & Beauvillain, 1988; Hernandez et. al, 1996). Given this finding, it has been argued that within-language priming may occur at the lexical level whereas cross-language priming is a postlexical process (Hernandez et al., 1996; Keatley & de Gelder, 1992).

The issue of how (or if indeed) information crosses from one lexicon to the other has also been approached using repetition priming. In this paradigm, presentation of an item leads to faster reaction times (RTs), better memory, or more accurate performance when the item is presented a second time (for a review, see Ellis & Ellis, 1998). The few studies that have looked at bilingual repetition priming have found little evidence of cross-language repetition priming especially for longer lags between items (Kirsner et al., 1980; Monsell et al., 1992). Hence, it appears that the presentation of a word in one language will only lead to activation of its translation equivalent for a limited amount of time. However, presentation of the same word in the same language does result in speeded recognition even when very long lags (lasting many seconds) between presentations are used (McKone, 1998).

The current article addresses this issue by looking at the nature of repetition priming (for both RTs and accuracy) within and between languages using pictures. Previous studies that have used lexical stimuli have found that cross-language semantic or repetition priming does not occur over longer lags. Work with bilinguals has revealed that naming of a picture in one language will result in activation of a word's translation (for a review see Kroll & de Groot, 1997). Hence, we expect that repetition priming using picture naming will result in both within- and between-language repetition priming. Of particular interest will be whether these two forms of priming are mediated by different mechanisms. As a review for the current set of studies, the nature of repetition priming in picture naming will be considered.

Repetition Priming and Picture Naming

The phenomenon of enhanced recognition of repeated items is well established (Bajo & Canas, 1989; Collins & Ellis, 1992; Durso & Johnson, 1979; Ferrand, Humphreys, & Segui, 1998; Wheeldon & Monsell, 1992). Furthermore, work has shown facilitation of target pictures is primed by the presentation of language-equivalent words (Mitchell & Brown, 1988; Wheeldon & Monsell, 1992), or by the presentation of phonologically similar word or nonword primes (Bajo & Canas, 1989; Collins & Ellis, 1992; Ferrand et al., 1998).

To further elucidate the nature of repetition priming, Monsell and colleagues (Monsell et al., 1992; Wheeldon & Monsell, 1992) conducted a series of studies looking at the effect of previously

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produced words in picture naming. Wheeldon and Monsell (1992) examined how the generation of a word—prime by a definition and by visual presentation of the word—facilitated the naming of a pictured object. Their results indicated facilitation of picture naming when the same word had previously been produced either by reading the word aloud or by producing the same word later in response to a prior definition of it. Because the stimuli used to elicit prime and probe production differed in perceptual similarity, Wheeldon and Monsell concluded that the repetition priming effect observed was due to repetition of processes involved in word production. In subsequent experiments, they found that repetition priming occurred only when both word form and pronunciation matched. When pronunciation was the same but meaning was different (e.g., *road–rode*) there was no repetition priming. In addition, Monsell et al. (1992), using a very similar paradigm, found that repetition resulted in significant facilitation but only when words were produced in the same language. When words were produced in opposite languages there was no facilitation. However, Monsell did find repetition priming for cognates. Hence, studies with monolinguals and bilinguals have revealed that both phonological and meaning overlap are necessary for repetition priming to occur during picture naming. Of interest, Kirsner et al. (1980) did not find repetition priming across languages (i.e., translation priming) at long lags using lexical decision. Hence, it appears that repetition priming is limited to conditions in which both meaning and form overlap. Taken together these results are consistent with the view that repetition priming in picture naming is due to an enhancement of the pathway between meaning activation and lexical activation.

Lexical Priming and Retrieval in Bilinguals

Unlike repetition priming studies with bilinguals, which have used for the most part a long lag, semantic priming studies have all used an immediate lag. Early work on semantic priming suggested that within-language priming is "automatic" or purely lexical (Grainger & Beauvillain, 1988). Furthermore, studies have found that cross-language semantic priming is less robust than within-language priming (Fox, 1996; Keatley & de Gelder, 1992; Tzelgov & Eben-Ezra, 1992) and may involve more postlexical processing (Hernandez et al., 1996). However, there is evidence that priming across languages can occur under conditions that discourage strategic processing (Altarriba, 1992). Results across studies suggest that cross-language priming is less robust than within-language priming.

The use of other paradigms has also led to differences between within- and cross-language priming. For example, Costa and colleagues (Costa, Caramazza, & Sebastian-Galles, 2000; Costa, Colome, & Caramazza, 2000) used a picture–word interference paradigm in which participants are asked to name a picture that has an embedded distractor. Costa and colleagues found larger facilitation within languages than between languages. In addition, they varied the time between presentation of a picture and a word distractor. Results revealed facilitation of picture naming by identical distractors in the same language at −200, 0, and 200 stimulus onset asynchrony (SOA). However, facilitation for identical distractors in the opposite language (i.e., translations) was found but only at −200 SOA. These results are consistent with the view that translations have a much shorter influence on word production than identical distractors. Costa, Miozzo, and Caramazza (1999) suggested that the increased facilitation within languages is due to phonological facilitation. In addition, it is possible that between-language distractors need to be processed semantically before they can have an influence on word production in the other language.

In addition to considering the difference between within- and cross-language priming, it has also been found that between-language semantic priming is asymmetrical with priming being larger from first language (L1) to second language (L2) than vice versa (Altarriba, 1991; Keatley & de Gelder, 1992; Keatley et al., 1994; Tzelgov & Eben-Ezra, 1992). More recent work with early bilinguals has shown that this pattern of asymmetry can be reversed with L2 becoming the stronger language for semantic priming (Altarriba, 1991; Hernandez et al., 1996), the naming of single pictures (Hernandez & Kohnert, 1999; Kohnert, Bates, & Hernandez, 1999; Kohnert, Hernandez, & Bates, 1998), and translation (Heredia, 1997). Within-language priming has also revealed that priming is larger in the weaker language (Hernandez et al., 1996). This suggests that the dominance of the language can play an important role in the magnitude of within- and between-language priming.

The nature of asymmetries in processing has also been investigated using picture naming. In general, these studies have found that naming of a picture is faster and/or more accurate in the first language (Chen & Ng, 1989; Kroll & Stewart, 1994; Potter, So, von Eckardt, & Feldman, 1984) or the more dominant language (Hernandez & Kohnert, 1999; Kohnert et al., 1998, 1999). Kroll and colleagues (Kroll, 1994; Kroll & de Groot, 1997; Kroll & Sholl, 1992; Kroll & Stewart, 1994; Sholl et al., 1995) have suggested that this asymmetry in processing can be attributed to weaker links between the lexicon in the weaker language and a conceptual representation.

The model presented by Kroll originally was termed the "revised hierarchical model" (Kroll, 1994; Kroll & de Groot, 1997; Kroll & Sholl, 1992; Kroll & Stewart, 1994; Sholl et al., 1995). However, more recently Kroll and de Groot (1997) have provided a more distributed lexical/conceptual model (DLC) of bilingual language representation (see Figure 1). This model is adapted from models by Levelt, Roelofs, and Meyer (1999) and Dell and O'Seaghdha (1992). It assumes that there exist two independent lexicons. These correspond to the lemma level in Levelt et al.'s model. These are connected to both lexical representations (i.e., which are phonological in nature in the picture naming task) and to conceptual representations.

Kroll and de Groot's (1997) model has been used to explain a number of phenomena in the bilingual literature, including picture naming, translation, and semantic priming (for a review, see Kroll & de Groot, 1997). Furthermore, it can be used to describe repetition priming both within and between languages. Specifically, within-language repetition priming in this model is due to the facilitation of links between the lemma level and the lexical and conceptual levels. However, activation from one language to the other is not done through lemma-to-lexical links. Rather priming must be mediated through conceptual links, which then serve to send activity to the other language lemma, which then result in lexical activation. This predicts that repetition priming at the lexical level will only occur within languages and not between languages, a finding that has been confirmed in the literature (Kirsner et al., 1980; Monsell et al., 1992). However, because the

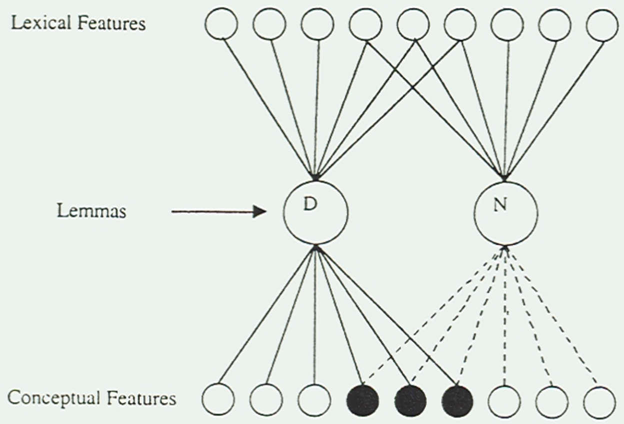

Figure 1. Kroll and de Groot's (1997) distributed lexical/conceptual model. From "Lexical and Conceptual Memory in the Bilingual: Mapping Form to Meaning in Two Languages," by J. F. Kroll and A. M. B. de Groot, in A. M. B. de Groot and J. F. Kroll (Eds.), *Tutorials in Bilingualism: Psycholinguistic Perspectives* (p. 190, Figure 6.4), 1997, Mahwah, NJ: Erlbaum. Copyright 1997 by Erlbaum. Adapted with permission.

lemma-lexical connections are not doted in this figure, it suggests that these connections are equally strong in both languages. Hence, this model in its current form would predict equivalent within-language repetition priming in the dominant and nondominant languages.

The current study is designed to further explore the nature of lexical, lemma, and conceptual representations during picture naming. To do this, we presented bilinguals with repeated pictures in a within-language (same picture, same response) and a between-language condition (same picture, different response). In Experiment 1, we used an immediate lag to establish the presence of repetition priming both within and between languages. In Experiments 2 and 3 (within- and between-language priming), we observed how a long lag affects the increase or decrease of repetition priming. On the basis of both previous studies and the model proposed by Kroll and de Groot (1997), within-language repetition priming should be larger than between-language priming. This is simply because within-language priming during picture naming involves both conceptual and phonological overlap whereas between-language repetition priming can only occur through conceptual links. The lag that we posit to affect the links between the lemma and lexical level should only affect the magnitude of within-language repetition priming.

Experiment 1: Within- Versus Between-Language Repetition Priming at 0 Lag

Method

Participants. Twenty-four Spanish–English bilingual college students participated in this study. The mean age of the group was 18.7 years (SD = 1.52 years). Of the 24 individuals tested, 18 were women and 6 were men. Participants were recruited through the participant pool in the Department of Psychology or from the general community at the University of California, Santa Barbara. They were given course credit or paid $5.00 for their participation. The Boston Naming Test (Kaplan, Goodglass, & Weintraub, 1983), a test of picture naming, was used to assure sufficient fluency in both languages. The items in this test vary from very simple (*bed*) to very complex (*trellis*). Previous work in our laboratory has normed this with bilingual populations (Kohnert et al., 1998). Scores on the Boston Naming Test revealed a mean score of 45.5 in English and a mean score of 24.7 in Spanish. Participants were chosen on the basis that they were right-handed, bilingual, and started learning English by the age of 7. General exclusion criteria included left-handedness and a history of speech, language, or hearing deficits. In addition, participants were excluded if they scored below 20 in either language on the Boston Naming Test.

Design, materials, and apparatus. A total of 132 black line-drawn pictures (as well as an additional practice set) of common nouns with their corresponding translation equivalents were selected from standardized sets (Abbate & La Chapelle, 1979; Morrison, Chappell, & Ellis, 1997; Snodgrass & Vanderwart, 1980). The pictures fit the following criteria. First, these pictures were identified from previous studies in our laboratory as yielding relatively low error rates in both languages for Spanish–English bilinguals. Second, the Kučera and Francis word frequency of the lexical items corresponding to these pictures was 50.5 occurrences per million (SD = 86.7, minimum = 1, maximum = 590). Third, items were chosen so that they were not orthographically similar across languages. Hence, no cognates were used in the current study. Each picture—with the exception of fillers—was presented twice to each participant. All pictures were optically scanned, edited, and presented as white-on-black line drawings appearing on a 12-in. monitor placed approximately 18 in. in front of each participant. The participants wore headphones with an attached microphone that was positioned near their mouth. The microphone was hooked up to a Carnegie Mellon button box (New Micros, Dallas, TX) to record the responses in milliseconds. All experiments were run using a StarMax 3000 computer (Motorola Computer Group, Tempe, AZ).

Eight conditions were formed by combining language, repetition, and condition. Pictures were either repeated or not and were either named in Spanish or in English. Finally, participants would either name both pictures in the same language (within-language condition) or name both pictures in different languages (between-language condition). Spanish responses were cued by the word *diga*, which translates to *say* in Spanish, and English responses were cued by the word *say*. The entire experiment consisted of 252 trials that were presented in four different lists. The experimental paradigm consisted of 120 test pictures (each presented twice) that had 12 filler trials preceded by 10 practice trials, with equal numbers of Spanish and English targets. Stimuli were counterbalanced so that each picture appeared in every condition across participants. The auditory cues alternated in a consistent pattern between trials with each picture presentation according to the condition (i.e., *say–diga*, *say–say*, *diga–diga*, *diga–say*).

Procedure. Participants were first given a set of papers that included informed consent, language history information, and an internally developed handedness questionnaire. Then, participants were fitted with headphones and seated in front of the computer screen. Each participant's information was recorded into the computer. They were instructed to name the pictured items as quickly and accurately as possible in the language indicated by the simultaneous auditory prompt (e.g., "*say* or *diga*, say in Spanish"). They were also instructed to press a key on the keyboard to begin each trial. The volume of the auditory cue was adjusted to a comfortable loudness for each participant. Participants were instructed to speak loudly and clearly and to avoid audible hesitations. Microphone sensitivity was adjusted as needed for each participant. The participant was given a practice set of pictures before receiving the experimental set.

Each trial proceeded in the following manner. Participants pressed a button on the computer keyboard to advance to begin the trial. As soon as a key was pressed, an auditory cue (*say* or *diga*) was presented simultaneously with the picture. The picture remained on the computer screen until a voice was detected by the button box. If no voice was detected the picture would automatically disappear after 2,500 ms and a "no response" was recorded. After this a new trial would begin.

Participants were tested individually in a quiet and separate room. A trained research assistant was present for the duration of the test. The research assistant recorded the participant's responses and recorded any technical errors, hesitations, or early detected voices. Each session was tape recorded to ensure accuracy during later verification of responses.

Data analysis. RTs were recorded for all accurately named pictures and entered into subsequent analyses. A response was counted as correct if it was produced clearly without audible hesitation in the target language, and if it corresponded to the dominant name of the picture, or an appropriate synonym for the picture presented (e.g., in English, the word *plane* was counted valid for the word *airplane*, and in Spanish, the word *serrucho* was counted correct for the word *sierra*). RTs corresponding to incorrect responses were excluded from subsequent analyses. In addition, we computed a set of difference scores by subtracting the RTs to pictures presented the second time from RTs to pictures presented the first time.

Results and Discussion

For the results reported here, we set the cutoff for statistical significance at $p < .05$. Only values for results that are above that threshold are reported.

Earlier we suggested that within-language priming should be larger than between-language priming and that repetition priming effects should be larger in Spanish than in English. Both of these hypotheses were tested with a 2 (repetition) × 2 (language) × 2 (condition, within vs. between) analysis of variance (ANOVA). As expected, repetition lead to a decrease in RTs, $F_1(1, 23) = 200.00$, $MSE = 41{,}117$, $F_2(1, 119) = 645.00$, $MSE = 65{,}711$. RTs were 424 ms faster during the second instance (989 ms) when compared with the first instance (1,413 ms). RTs were also faster when language remained the same across repetitions (1,169 ms) than when languages changed across repetitions (1,233 ms), $F_1(1, 23) = 19.38$, $MSE = 9{,}839$; $F_2(1, 119) = 30.00$, $MSE = 31{,}658$.

The most interesting effects were the interactions between repetition, language, and condition. First of all, the hypothesis that within-language repetition priming was larger than between-language repetition priming was supported in an interaction between repetition and condition, $F_1(1, 23) = 36.03$, $MSE = 10{,}315.35$; $F_2(1, 119) = 36.00$, $MSE = 31{,}239$. Furthermore, it was found that repetition interacted with language and condition, $F_1(1, 23) = 8.18$, $MSE = 4{,}467$; $F_2(1, 119) = 1.55$, MSE
T1 $= 48{,}253.1396$ (see Table 1).

To further understand the repetition priming effects, analyses from difference scores (first minus second instance) were conducted. As predicted, repetition effects were larger within language (491 ms) than between language (334 ms), $F(1, 23) = 29.63$, $MSE = 23{,}889$. Furthermore, language interacted with condition, $F(1,23) = 8.01$, $MSE = 8{,}863$. Planned comparisons on the Language × Condition interaction revealed that repetition priming effects were larger in Spanish than in English in the within-language condition, $F(1, 23) = 8.66$, $MSE = 8{,}863$, but not in the between-language condition. Hence, the increased repetition priming effect in Spanish (the weaker language) was only observed in the within-language condition.

Errors

The results from the analysis of errors using a 2 (repetition) × 2 (language) × 2 (condition) ANOVA supported the main findings of the RT analysis. Again repetition led to a reduction in errors (23.75 vs. 18.75), $F_1(1, 23) = 12.95$, $MSE = 91.03$; $F_2(1, 119) = 35.60$, $MSE = 131.95$. Unlike RTs, there were more errors in Spanish (29) than in English (13), $F_1(1, 23) = 32.85$, $MSE = 356.40$; $F_2(1, 119) = 53.85$, $MSE = 897.29$. Furthermore, repetition led to a larger decrease in errors in the within-language condition (24.5 vs. 16.0) than in the between-language condition (23.0 vs. 21.5).

Table 1
Mean Reaction Times (in ms) and Percent Errors Across Repetition Conditions in Experiment 1

	First instance		Second instance (repetition)	
Language	RT (*SEM*)	PE (*SEM*)	RT (*SEM*)	PE (*SEM*)
	Within language			
English	1,416 (37.89)	17 (2.45)	938 (23.47)	9 (1.22)
Spanish	1,434 (39.39)	32 (2.86)	885 (26.13)	23 (2.25)
	Between language			
English	1,405 (37.56)	14 (2.04)	1,050 (28.17)	13 (1.84)
Spanish	1,394 (36.74)	32 (3.47)	1,081 (33.07)	30 (2.86)

Note. RT = reaction time; PE = percent error.

The results so far provide partial support for the DLC model. Repetition led to a larger decrease within languages than between languages for both errors and RTs. Other results, however, were not consistent with the predictions of the DLC model. First of all, there was no language asymmetry of between-language repetition priming. Furthermore, repetition priming was larger in Spanish than in English but only in the within-language condition. That is, picture naming in Spanish benefits more from repetition than naming in English. For the between-language condition, there was no difference across languages. One possible account for this finding could be that the increased repetition priming in Spanish occurred because of stronger activity at the conceptual level. However, this would predict larger within-language repetition for English not Spanish. Another possibility is that connections between the lemma level and the lexical–phonological level are weaker in the nondominant language, Spanish. Because these connections are weaker in Spanish, then activation of the lexical label in this language should be further enhanced by repetition. If this were the case, then repetition would be larger in Spanish because it serves to temporarily enhance the activity between these levels.

Experiment 2 was designed to further test this assumption by introducing lag. Although previous studies using lag have found a larger reduction of the repetition priming effect for nonwords compared with words (McKone, 1998), no study to date has used lag to explore the nature of repetition priming in bilinguals. If, in fact, the asymmetric repetition priming effect is due to a temporary enhancement of the connections between lexical-phonological and lemma level representations, then increased lag should result in a reduction or elimination of this within-language asymmetry.

Experiment 2: Within-Language Repetition Priming at 0 and Long Lags

In Experiment 2, within-language priming will be observed across languages at 0 and long (more than 30 items) lags. The results should fall in line with those observed in Experiment 1.

Namely, repetition priming should be larger in Spanish than in English at the 0 lag. Of particular interest is the effect of lag. If lag affects the reduction of lemma–phonological activity, then we should observe a reduction or elimination of this asymmetry.

Method

Participants. Twenty-four college students participated in this study. The mean age of the group was 19.4 years (SD = 1.39). Of the 24 individuals tested, 16 were women and 8 were men. Participants were recruited through the participant pool in the Department of Psychology at the University of California, Santa Barbara. They were given course credit or paid $5.00 for their participation. All participants completed health and language history questionnaires prior to the experiment. The Boston Naming Test (Kaplan et al.,1983) was administered following the experiment. The participants had a mean score of 48.3 in English and a mean score of 25.9 in Spanish. Participants were chosen on the basis that they were right-handed, bilingual in Spanish, and started learning English by the age of 7. General exclusion criteria included left-handedness and a history of speech, language, or hearing deficits.

Procedure, design, materials, and analysis. We used The same 132 black line-drawn pictures as in Experiment 1. All pictures and general methodology were identical to those used in Experiment 1, except for two things. Participants were shown pictures and asked to name them in the same language during a block of trials. Hence, the language changed only between blocks. The order of presentation was counterbalanced so that half the time English was first and half the time Spanish was first. Repetition, language, and lag were crossed to create eight different conditions. Furthermore, pictures were repeated immediately or over a number of trials. The long-lag condition was on average 63 trials apart (SD = 14, minimum = 36, maximum = 93). Like Experiment 1, an auditory cue was used to indicate the language response, which was kept constant across a block of trials. Hence, there was no mixing of languages in a particular block of trials. Errors were recorded by an experimenter who stayed in the room during the entire testing session and were reviewed later for accuracy. All RTs on error trials were excluded from subsequent analyses.

Results and Discussion

T2 Table 2 presents the mean response latencies and percent errors for all conditions. We observed that responses were faster and more accurate in English than in Spanish. In addition, repetition served to reduce both errors and RT. Responses were more accurate in English than in Spanish. Finally, it should be noted that repetition priming effects were larger in Spanish than in English, but only in the 0-lag condition. At the longer lag, there was no difference in the magnitude of repetition priming.

Table 2
Mean Reaction Times (in ms) and Percent Errors Across Repetition Conditions in Experiment 2

	First instance		Second instance (repetition)	
Language	RT (SEM)	PE (SEM)	RT (SEM)	PE (SEM)
	Immediate lag			
English	983 (28.58)	3 (1.43)	800 (33.68)	3 (1.22)
Spanish	1,109 (38.17)	14 (2.65)	806 (34.50)	9 (1.84)
	Long lag			
English	977 (38.17)	4 (1.02)	866 (33.07)	3 (1.63)
Spanish	1,114 (40.62)	10 (1.84)	970 (37.15)	6 (1.43)

Note. RT = reaction time; PE = percent error.

All these observations were confirmed by a 2 (language) × 2 (repetition) × 2 (lag) ANOVA. There was a main effect of language, $F_1(1, 23) = 10.24$, $MSE = 40{,}981$; $F_2(1, 79) = 24.31$, $MSE = 43{,}692$; repetition, $F_1(1, 23) = 183.87$, $MSE = 8{,}979$; $F_2(1, 79) = 178.93$, $MSE = 65{,}711$; and lag, $F_1(1, 23) = 24.25$, $MSE = 29{,}411$; $F_2(1, 79) = 30.48$, $MSE = 30{,}575.03$. In addition, there were Language × Repetition interactions, $F_1(1, 23) = 5.59$, $MSE = 12{,}709$; $F_2(1, 79) = 17.97$, $MSE = 10{,}207$; Language × Lag, $F_1(1, 23) = 4.69$, $MSE = 7{,}595$; $F_2(1, 79) = 5.76$, $MSE = 19{,}432$; Repetition × Lag, $F_1(1, 23) = 26.56$, $MSE = 6{,}004$; $F_2(1, 79) = 33.63$, $MSE = 15{,}950$, and a three-way Language × Repetition × Lag interaction, $F_1(1, 23) = 4.26$, $MSE = 5{,}240$; $F_2(1, 79) = 5.85$, $MSE = 10{,}471$ (see Figure 2). F2

The error analysis revealed a main effect of language, $F_1(1, 23) = 9.57$, $MSE = 225.46$; $F_2(1, 79) = 16.00$, $MSE = 310.44$; repetition, $F_1(1, 23) = 14.75$, $MSE = 16.95$; $F_2(1, 79) = 12.25$, $MSE = 48.25$; and a Language × Repetition interaction, $F_1(1, 23) = 4.43$, $MSE = 27.29$; $F_2(1, 79) = 8.63$, $MSE = 44.91$. Even though participants had a greater benefit of naming a picture when repeating it in Spanish, their error rate was higher in Spanish than in English (10% for Spanish and 3% for English).

The results from both these analyses show that although repetition effects occur in both languages, they are asymmetric for both RTs and errors. However, the asymmetric effects interacted with language and lag for RTs. This was reflected in the Language × Repetition × Lag interaction for RTs. To further explore this effect, we ran separate two-way (Language × Repetition) ANOVAs, one for the 0-lag condition and one for the longer lag condition. Results at 0 lag revealed main effects of language, $F_1(1, 23) = 5.37$, $MSE = 19{,}620.88$; $F_2(1, 79) = 10.42$, $MSE = 23{,}131.18$; repetition, $F_1(1, 23) = 138.92$, $MSE = 10{,}209.29$; $F_2(1, 79) = 176.20$, $MSE = 26{,}856.88$; and a Language × Repetition interaction, $F_1(1, 23) = 7.98$, $MSE = 10{,}840.83$; $F_2(1, 79) = 25.38$, $MSE = 8{,}865.81$. Post hoc analyses of the Language × Repetition interaction revealed a significant difference between Spanish and English items, but only for the first instance, $F_1(1, 23) = 17.57$, $MSE = 10{,}840.83$; $F_2(1, 79) = 52.62$, $MSE = 8{,}865.81$. Results at the longer lag revealed a main effect of language, $F_1(1, 23) = 12.45$, $MSE = 28{,}005.97$; $F_2(1, 79) = 23.78$, $MSE = 39{,}640.74$; and repetition, $F_1(1, 23) = 84.07$, $MSE = 4{,}850.49$; $F_2(1, 79) = 67.25$, $MSE = 18{,}997.87$.

The results from the current experiment revealed a number of interesting findings. First, the magnitude of repetition priming was larger in the 0-lag condition compared with the long-lag condition. Second, there was larger repetition priming in Spanish than in English, but only at the 0 lag. Specifically, repetition speeds naming of Spanish pictures by close to 170 ms compared with only 60 ms for English pictures in the 0-lag condition. However, in the long-lag condition, repetition speeded Spanish pictures by 140 ms versus 111 ms in English. These findings are consistent with the notion that naming of pictures that have weaker links between lemma and lexical–phonological levels benefit more from repetition. The fact that this effect appears at 0 lag suggests that this benefit is very short lived. With longer lags, repetition effects become more symmetrical and language fluency shows up as a main effect in RT. This is consistent with the view that asymmetric

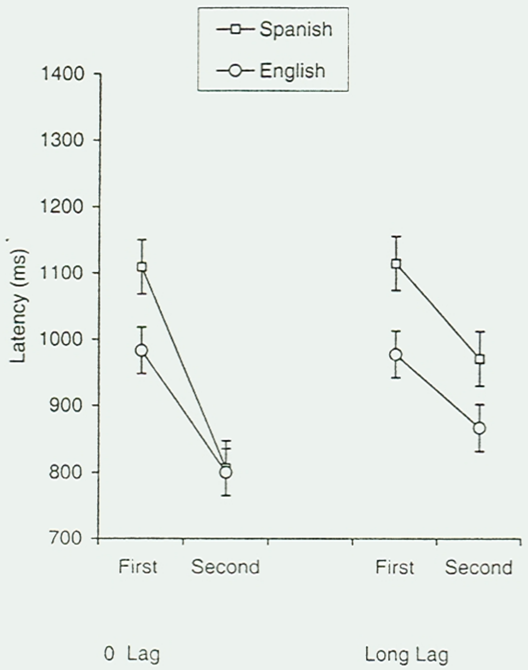

Figure 2. Effect of language on repetition priming as a difference score in Experiment 1 (within-language condition).

within-language repetition priming is due to enhanced activity of weaker links in the nondominant language during repetition, a point we will return to later.

The fact that repetition priming involves a phonological component also has relevance for the nature of cross-language repetition priming. The lack of phonological overlap between the first and second instance should lead to a reduction in the magnitude of repetition priming across languages. In addition, lag could serve to further clarify the nature of cross-language asymmetries. In Experiment 1, there was no asymmetry in cross-language priming. This was somewhat surprising because the DLC model would predict an asymmetry between languages. Specifically, it would predict that priming from one language to the other should occur through a conceptual route. If this is correct, we should expect a different pattern of asymmetry. First, priming should be larger from Spanish to English than vice versa. Why might that be? One should recall that activation from the conceptual to the lemma level is weaker in Spanish. Hence, naming of pictures in Spanish activates both Spanish and English lemmas. However, naming of pictures in English results in much smaller activation of Spanish lemmas. Second, if lag affects the lexical–lemma connections, it should not result in a reduction of cross-language repetition priming. These predictions run counter to the results we observed in Experiment 1, a point we will return to in the General Discussion.

Experiment 3: Between-Language Repetition Priming at 0 and Long Lags

Method

Participants. Twenty-four college students participated in this study. The mean age of the group was 18.74 years (SD = 1.22). Of the 24 individuals tested, 18 were women and 6 were men. The participants were recruited through the participant pool in the Department of Psychology at the University of California, Santa Barbara. They were given course credit or paid $5.00 for their participation. All participants completed health and language history questionnaires prior to the experiment. The Boston Naming Test (Kaplan et al., 1983) was administered following the experiment. The participants had a mean score of 47.3 in English and a mean score of 27.3 in Spanish. Participants were chosen on the basis that they were right-handed, bilingual in Spanish, and started learning English by the age of 7. General exclusion criteria included left-handedness and a history of speech, language, or hearing deficits.

Procedure, design, materials, and analysis. We used the same 132 black line-drawn pictures as in Experiment 2. All pictures and general methodology were identical to those used in Experiment 3, except for two things. Participants were asked to name pictures in both languages during a block of trials. Repetition, language (Spanish–English vs. English–Spanish), and lag were crossed to create eight different conditions. As in Experiments 1 and 2, an auditory cue was used to indicate the language response. However, unlike Experiment 2, the language of response was not kept constant across a block of trials. Errors were recorded by an experimenter who stayed in the room during the entire testing session and were reviewed later for accuracy. All RTs on error trials were excluded from subsequent analyses.

Results and Discussion

Table 3 presents the mean response latencies and percent errors for all conditions. Because of the cross-language form of priming, we analyzed data in a slightly different manner than Experiment 2. Rather than making language a factor, we paired items that were repeated. Hence, we analyzed data as Spanish–English or English–Spanish pairs. The results revealed that repetition served to reduce RT only. There was no effect of language (due to the collapsing of Spanish and English across our conditions). However, there was a Repetition × Language interaction. Specifically, repetition priming from Spanish to English was larger than it was from English to Spanish. Surprising, lag did not affect RTs or errors either directly or through an interaction with other variables (see Figure 3).

All these observations were confirmed by a 2 (language) × 2 (repetition) × 2 (lag) ANOVA. There was a main effect of repetition, $F_1(1, 23) = 22.96$, $MSE = 22{,}663$; $F_2(1, 79) = 36.98$, $MSE = 34{,}391$; and a Repetition × Language interaction, $F_1(1, 23) = 24.25$, $MSE = 29{,}411$; $F_2(1, 79) = 8.85$, $MSE = 43{,}624$.

Table 3
Mean Reaction Times (in ms) and Percent Errors Across Repetition Conditions in Experiment 3

	First instance		Second instance (repetition)	
Language	RT (*SEM*)	PE (*SEM*)	RT (*SEM*)	PE (*SEM*)
Immediate lag				
English–Spanish	1,216 (38.58)	3 (1.43)	1,158 (36.95)	3 (1.22)
Spanish–English	1,276 (48.58)	14 (2.65)	1,107 (36.74)	9 (1.84)
Long lag				
English–Spanish	1,186 (42.05)	4 (1.02)	1,147 (43.89)	3 (1.63)
Spanish–English	1,297 (54.91)	10 (1.84)	1,146 (32.86)	6 (1.43)

Note. RT = reaction time; PE = percent error.

between-language repetition priming is due to activation of links between the conceptual level and the lemma level. It does not occur because of direct links between items at the lemma level.

General Discussion

The results from the current experiments can be summarized quite clearly: Repetition priming between languages is mediated by different processes than those that mediate within-language priming. As predicted, within-language repetition priming was larger than between-language priming across all experiments. Furthermore, in Experiments 2 and 3 we found that lag led to a reduction in within-language priming but not between-language repetition priming. Finally, we found that language and lag interacted with the magnitude of within-language repetition priming but only in the 0-lag condition. Taken together, these results are consistent with the view that repetition priming between languages is modulated by different factors than within-language repetition priming.

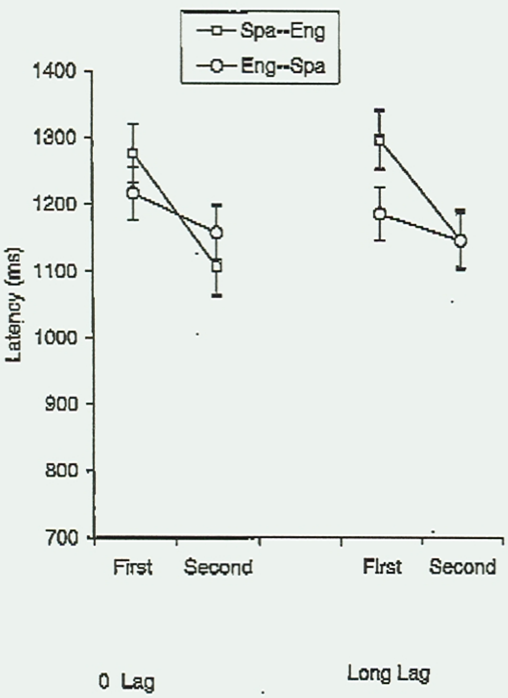

Figure 3. Language × Condition interaction on repetition priming as a difference score in Experiment 2. Eng = English; Spa = Spanish.

result of enhancement of both conceptual-lemma links and lemma-lexical links. However, cross-language repetition priming is due to enhancement of conceptual-lemma links only. Hence, it is smaller. Second, within-language repetition priming interacts with lag whereas cross-language repetition priming does not. The enhancement of links between the lemma and lexical-phonological levels that occurs at 0 lag has no effect on the magnitude of cross-language priming but does affect within-language priming. Third, the asymmetric increase in within-language repetition priming in Spanish decays across lag. Again, this is consistent with the view that increasing lag leads to a reduced enhancement of links between the lemma level and the lexical-phonological level. The implication of this asymmetric within-language effect also has implications for the DLC model. Specifically, it suggests that links from both the lexical level and the conceptual level to the lemma level are weaker in the nondominant language. When repetition occurs close in time there is an enhancement of these weaker links that results in an increased repetition effect.

Some aspects of the current data could be explained using alternative frameworks. One possible framework would suggest that the asymmetries we have observed have to do with the difficulty of the task. For example, recent work by Ostergaard (1998) has found that the ease of task modulates the magnitude of repetition priming. When using a naming task, Ostergaard found that repetition priming increased with degradation. The current study adds to this view by suggesting that the reduction is due to enhancement of links between the lemma level and the lexical level. When these connections are weak, repetition can serve to enhance them to a greater extent than when they are strong.

The current study could also be explained by the model proposed by Costa and colleagues (Costa & Caramazza, 1999; Costa, Caramazza, & Sebastian-Galles, 2000; Costa, Colome, & Caramazza, 2000; Costa et al., 1999). In these studies, they have found that activation of lexical items in the nonselected language occurs at the semantic level but does not spread to the phonological level. That is, when the word *house* is named for the picture of a house, there is activation of the translation *casa*. However, words that are phonologically related to the translation (i.e., *masa*) are not activated. These results suggest that selection of a word does not involve the activation of lexical items in a translation's phonological neighborhood. Furthermore, Costa, Caramazza, and Sebastian-Galles (2000) found that pictures of cognates are named faster than noncognates, an effect that is larger in the nondominant language. This suggests that lexical items in the nondominant language receive more facilitation from the alternate language than those in the dominant language. Taken together, these results support a model in which the activation of a lexical item by its translation depends on the relative fluency in each

Orig. Op.	OPERATOR:	Session	PROOF:	PE's:	AA's:	COMMENTS	ARTNO:
1st DCT-msh, 2nd DCT-msh	deangeln	8					9

language. Of interest, these results (like ours) can be accounted for by the DLC model. In this view, activity of a translation is conceptually mediated and hence does not spread to the phonological neighbors. Furthermore, dominance will modulate the extent to which a translation is active.

The current study also extends previous studies using repetition priming. For example, previous studies have been based on the fact that no cross-language repetition priming is observed at long lags. By using pictures, we did observe both within- and between-language priming at various lags. Furthermore, it was found that only within-language repetition priming was affected by lag. Future studies could explore this phenomenon further. One possible extension would be to look at the effect using lexical stimuli. One would expect that within-language asymmetries should be present for words as well. Second, one could also further explore the nature of between-language repetition priming. If this effect is purely lexical, one would expect that it would be modulated by the degree of physical overlap between words in each language. That is, cognates would show the largest repetition priming effect. Noncognates would show no repetition priming effect at long lags. One could further extend these studies by looking at words that are written the same across languages but have different meanings. Language specificity would predict that shared orthographic forms would not be sufficient to ensure cross-language repetition priming. To find cross-language repetition priming at long lags, there must be shared form and shared meaning.

Finally, our results also revealed a difference in the asymmetries seen in Experiments 1 and 3. Namely, there were no cross-language priming asymmetries in Experiment 1 but there were cross-language asymmetries in Experiment 3. This effect is most likely due to strategic differences. Experiment 1 involved continuous switching between languages. Studies that have looked at language switching (Hernandez & Kohnert, 1999; Mueter & Allport, 1999) have posited that processing of mixed-language lists involves increased executive function compared with processing of single-language lists. This suggests that differences in attentional processing can change the presence of language asymmetries. The switching difference would also explain why RTs for Experiments 2 (no language switching) and 3 (language switching) differ so much. Future studies should investigate this more carefully.

In summary, the current study supports and extends the DLC model. First, our results posit that connections between the lexical level and the lemma level are most likely weaker in the nondominant language. Most important, they are consistent with the view that priming between languages involves conceptual processing and is not the product of direct links between lexical items at the lemma level.

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