Homographic Self-Inhibition and the Disappearance of Priming: More Evidence for an Interactive-Activation Model of Bilingual Memory

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Abstract

This paper presents two experiments providing strong support for an interactive-activation interpretation of bilingual memory. In both experiments French-English interlexical noncognate homographs were used, i.e., words like *fin* (= "end" in French), *pain* (= "bread" in French), that have a distinct meaning in each language. An All-English condition, in which participants saw only English items (word and non-words) and a Mixed condition, with half English and half French items, were used. For a set of English target words that were strongly primed by the homographs in the All-English condition (e.g., *shark*, primed by the homograph *fin*), this priming was found to disappear in the Mixed condition. We suggest that this is because the English "component" of the homograph is inhibited by the French component which only becomes active in the Mixed condition. Further, recognition times for these homographs as words in English were significantly longer in the Mixed condition and the amount of this increase was related to the relative strength (in terms of printed-word frequency) of the French meaning of the homograph. We see no reasonable independent-access dual-lexicon explanation of these results, whereas they fit easily into an interactive-activation framework.

Introduction

In the last two decades numerous arguments have been made for and against separate-access independent-lexicon theories of bilingual memory organization. There are essentially two opposing views in this debate. There are those who believe that each of a bilingual's languages is, to a large extent, "compartmentalized" in independent, language-specific areas. Results from Macnamara & Kushnir (1971), Grosjean & Soares (1986), Grosjean (1989), Gerard & Scarborough (1989), etc. support this view. Further, bilingual aphasia data (e.g., Albert & Obler, 1978) and recent PET studies (Klein et al., 1995) give support to the independent, dual-lexicon model of bilingual memory. However, evidence has also been mounting on a contradictory front — namely, that bilingual memory may resemble the highly overlapping, densely interconnected structure that characterizes monolingual memory. These models are usually called interactive-activation models (McClelland & Rumelhart, 1981).

Persuasive evidence for this latter point of view has come from cross-lingual priming data (Kolers, 1966; Meyer & Ruddy, 1974; Schwanenflugel & Rey, 1986; Beauvillain & Grainger, 1987; Beauvillain, 1992; Chen & Ng, 1989; De Groot & Nas, 1991; Hernandez, Bates, & Avila, 1995; French & Ohnesorge, 1996; etc.). This body of research would suggest that some type of interactive-activation model is the most accurate model of bilingual memory.

In this paper we will present two experiments that, in our opinion, cannot be explained by any separate-access dual-lexicon model of which we are aware. We believe that these results are best interpreted as evidence for interactive-activation between languages.

Overview of the two experiments

The first experiment involves priming using interlexical homographs — words that have an identical spelling but a distinct meaning in each of two languages. Some examples of French-English homographs are: *fin* (= "end" in French), *pain* (= "bread" in French), *champ* (= "field" in French), etc. We selected a certain number of these homographs that strongly prime English target words in a monolingual English context. For example, in an English-only context, *ride* (which in French means "wrinkle") primes *horse*, *fin* primes *shark*, and so on. We discovered that this priming disappears if French items (words and nonwords) are mixed in with the English items that are presented. Exactly why this priming disappears will be discussed in detail later in this paper, but for now, suffice it to say that this phenomenon has a fairly simple explanation in the context of an interactive-activation model. However, we cannot imagine any explanation for it in a separate-access dual-lexicon framework.

The second experiment, like the first, had two conditions: an All-English condition in which participants saw exclusively English items (words and nonwords) and a Mixed condition where they saw an equal number of items in French and in English. Their task was to determine whether or not each item presented was (or was not) a word in English. In the Mixed condition of the first experiment, we observed a disappearance of priming by homographs of English target words. We reasoned that perhaps the French component of the homograph — not active in the All-English condition, but active in the Mixed condition — was *inhibiting* the activation of the English component of the homograph responsible for the priming of English target words in the All-English condition. This would imply that in the Mixed condition either the English component of the homograph was less active than in the All-English condition or its rise time to full activation was taking longer. In either case, this leads to a clear prediction about how long it should take to recognize a homograph as a word in English. The prediction is this:

If Δ_{hom} is the average increase in time required to recognize an interlexical homograph in the Mixed condition compared to the All-English condition and

if $\Delta_{English\text{-}word}$ is the average increase in time required to recognize a normal (i.e., non-homograph) English word in the Mixed condition compared to the All-English condition,

then

$$\Delta_{hom} > \Delta_{English\text{-}word}$$

A separate-access dual-lexicon model — which would have no place for specific inhibitory effects from the "French component" of a homograph — would presumably predict an approximately constant increase in the amount of time required to recognize an English word (*any* English word, homograph or non-homograph) as a word in English when going from the All-English to the Mixed condition. This might be because of the additional amount of time required to switch lexicons (for example, when the word immediately preceding the current word had been in French) or to an overall slowing due to the increased load of concurrently activating both English and French.

Our experimental data agreed with the prediction of the interactive-activation model. In going from the All-English to the Mixed condition, the increase in reaction time *is, in fact, significantly greater* for homographs than for non-homograph English words. This is evidence in support of an interactive-activation interpretation of bilingual memory. Furthermore, it is difficult to see how any dual-lexicon model could explain this difference.

Further, as part of this second experiment, we looked at reaction times to a subset of the full set of homographs used in the experiment. This subset was made up of *unbalanced* homographs — in other words, homographs whose printed word frequency was higher in one language than in the other. We considered two types of these unbalanced homographs — namely:

- HE-LF (High-English/Low-French): Those whose printed-word frequency was high in English and low in French, such as *ride* ("wrinkle" in French) or *if* ("yew tree" in French);
- LE-HF (Low-English/High-French): Those whose printed-word frequency was low in English and high in French, such as *fin* ("end" in French) or *champ* ("field" in French).

High frequency was defined for both languages as words among the 1000 most common words of the language; low frequency was defined as words whose rank was greater than 3000 in both languages (Kucera & Francis, 1967; Baudot, 1992). This was the definition used in French & Ohnesorge (1995).

The two models we are considering make different predictions with respect to the interaction of Context (All-English, Mixed) and Homograph type (LE-HF, HE-LF). The separate-access dual-lexicon model predicts no interaction whereas an interactive-activation model does predict an interaction. This interaction is predicted for the following reason: the presence of French in the Mixed condition would produce greater activation in the "French half" of LE-HF homographs than in the "French half" of HE-LF homographs. This, in turn, should produce greater interference by the "French half" on the "English half" for LF-HF homographs than for HE-LF homographs. Thus, in the Mixed condition when comparing LE-HF and HE-LF homographs, it should be comparatively *harder* to recognize the former as words in English.

Once again, what we observed fits the latter prediction for an interactive-activation model. It turns out that in the Mixed condition compared to the All-English condition, it is more difficult to recognize LE-HF homographs than HE-LF homographs. As before, an interactive-activation model of bilingual memory has little trouble accommodating this data; on the other hand, it is not in the least clear how an separate-access dual-lexicon model would explain these differences.

Experimental design

Experiment 1: Disappearance of Homograph Priming

Participants

Forty-eight members of the Middlebury community participated: 18 faculty from the Middlebury French department and summer French school, 19 students identified by faculty as bilingual, 4 high school French instructors and 7 local residents. All participants had extensive experience with both French (average: 30 years) and English (32 years).

Stimuli

The critical stimuli were 41 prime-target pairs. The prime was a non-cognate English-French homograph and the target was an English word (e.g. *fin-shark*). The pairs were generated through a pilot procedure. The remaining stimuli were filler items used to produce the All-English or Mixed (i.e., French-English) context in which the size of the priming effect could be assessed. In the All-English context there were only English items (i.e., words and regular non-words). In the Mixed condition, half of the context stimuli were French items, half were English.

Procedure

Participants were randomly assigned to a condition of the Context variable (Mixed or All-English). They were seated approximately 500 mm in front of the computer monitor. A Power Macintosh 7100 running PsyScope (Cohen, MacWhinney, Flatt, & Provost, 1993) presented the stimuli and collected the data. Instructions for the lexical decision task were presented on the screen in French for the mixed context and English for the All English context. "Press the Green button if the second stimulus is a word in *either* French or English". Participants completed a brief practice session. Each trial proceeded as follows. A 500 ms fixation point, a priming stimulus for 100 ms, a 50 ms blank interval, and finally the stimulus for lexical decision was presented until response. Observers responded to 456 experimental trials with a rest period at the midway point. Feedback in the form of a beep was provided for incorrect responses. Overall, 50% of the stimuli for lexical decision were words and 50% were non-words. The data of interest were the lexical decision times for the critical targets. These could be preceded by three types of primes: French-Unrelated, English-Unrelated, Homograph-Related. The current paper is concerned with the effect of language context on semantic priming, in the interest of brevity we will only present the data for the latter two types of primes.

Results

Subject means for the English-Unrelated and Homograph-Related conditions were calculated and submitted to a mixed ANOVA. The interaction of Context (All-English, Mixed) X Prime-Relatedness (English-Unrelated, Homograph-Related) was significant, $F_1(1,46) = 7.52$, $p < .01$; $F_2(1,40) = 3.95$, $p = .05$. Inspection of the results displayed in Figure 1 reveals a substantial priming effect (62 ms.) in the All-English condition but almost no facilitation (12 ms) in the Mixed condition. Analysis of the derivative simple effects supports the conclusion that there was a substantial semantic priming effect in the All-English condition $F(1,46) = 22.52$ and $F(1,40) = 24.18$ by subjects and items, respectively, but no priming in the Mixed condition $F(1,46) = .752$, $F(1,40) = 1.503$.

To summarize, we considered a set of English target words that pilot studies showed were strongly primed by the homographs we had chosen (e.g., *fin* primed the English target word *shark*, *ride* primed *horse*, etc.). We then determined the amount of priming of the target words by the homographs in an All-English condition by comparing reaction times to the target words (e.g., *shark*) when they were preceded by unrelated words (e.g., *cup*) as opposed to when they were preceded by related homographs (e.g., *fin*). In the All-English condition, we recorded a substantial and highly significant average priming effect of 62 ms. (unprimed targets: 693 ms vs. primed targets: 631 ms.). However, in the Mixed condition (i.e., when the same homograph-target pairs were seen in a context that included French words and regular nonwords), the priming effect dropped to 12 ms (unprimed: 701, primed: 689 ms) and was no longer significant. In other words, in the Mixed condition, the strong priming observed in the All-English condition essentially disappears.

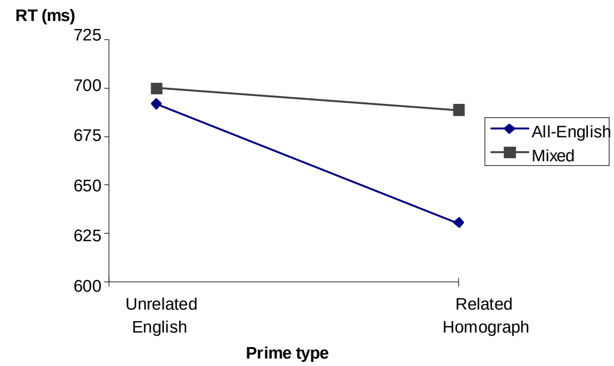

Figure 1. Reaction times to the set of target words shows disappearance of priming by homographs in the Mixed condition.

Experiment No. 2: Homographic "self-inhibition"

Participants

Twenty members of the Middlebury community; 10 faculty from the French department, 8 undergraduates and 2 local residents participated. All had extensive experience with both French (average: 24 years) and English (31 years).

Stimuli

The critical stimuli consisted of a set of 65 French-English homographs. This set included the forty-one homographs that were used as primes in experiment one. The filler stimuli used to create the context (Mixed or All English) were the same as in Experiment 1.

Procedure

The computer hardware and software used were as in Experiment 1. The experimental instructions were read from the screen. The participants were asked to classify the stimuli they would see by pressing one key if the stimulus was a word in English, and another key if the stimulus was not a word in English. All participants were given the same instructions, printed in English. At the conclusion of a 40-trial practice session, the participants initiated a series of 650 experimental trials. There were three rest periods at equal intervals during the experimental trials. Feedback in the form of a beep was provided for incorrect responses. The experiment was conducted using a mixed factorial design with two independent variables. Context was between-subjects with two levels (All-English and Mixed). Word Type was within-subjects with two levels (English

Word and French-English Homograph). Participants were randomly assigned to All-English or Mixed conditions.

Results

For all homographs Participants were asked to judge whether the letter-string that appeared on the computer screen was a word in English. In the All-English condition, the participants saw only English items (words and regular nonwords). In the Mixed condition, half of the items were French but the task was still to decide if the letter-string that appeared was a real word in English. As above, a dual-lexicon model would predict increased reaction times in the Mixed condition due to the additional time required to switch from one lexicon to another. But this predicted increase should be the same for all English words, whether homographs or normal (i.e., non-homograph) English words. However, as Figure 2 shows there is a significantly *greater* average increase in recognition reaction time for homographs.

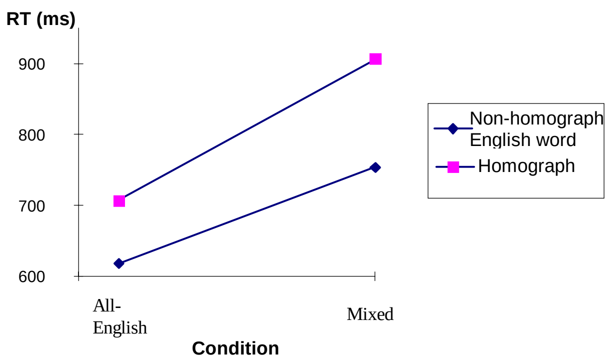

Figure 2. Significantly greater increase in reaction time for homographs in the Mixed condition than for non-homograph English words

This first analysis was a mixed factorial ANOVA with two factors. Context (All English, Mixed French-English) was a between-subject variable; the within-subject variable was Stimulus Type (English Word and English-French Homograph). There was a main effect of Context, $F(1,18) = 17.5$, $p < .001$. The main effect of stimulus type was also significant, $F(1,18) = 108.9$, $p = .0000$. Finally, the interaction of Context and Stimulus Type was also significant, $F(1,18) = 5.6$, $p = .03$. In order to examine the inhibition effect with items as the unit of analysis, the average response time for each of the 65 homographs was calculated for the All English condition and for the Mixed condition. A one-tailed dependent samples T-test revealed a significant difference of 217 ms, $T(64) = 7.74$, $p = .0001$.

For HE-LF and LE-HF homographs We then compared two types of homographs within the full set of homographs used. We called these *unbalanced* homographs. They consisted of two groups: those with a low printed-word frequency in English and a high printed-word frequency in French (designated LE-HF homographs, words such as *fin* (= "end" in French), *champ* (= "field" in French), etc. and those with a high printed-word frequency in English and a low printed-word frequency in French (designated HE-LF homographs, words such as *ride* (= "wrinkle" in French), *if* (= "yew tree" in French), etc. There was a clear difference in the increase in reaction time depending on the amount of "dominance" (in terms of printed-word frequency) of the French part of the homograph over the English part. The greater the French "frequency dominance," the slower the recognition of the homograph as an English word in the Mixed Condition. Specifically, for HE-LF homographs, those in which there should be the least interference from an activated French component, recognition times went from 602 to 735 ms between the All-English and the Mixed conditions (i.e., a difference of 133 ms). However, for LE-HF homographs, those in which the most interference from the French component could be expected, recognition times went from 765 ms in the All-English condition to 1097 ms in the Mixed condition, in other words, an increase of 332 ms. These results are shown in Figure 3.

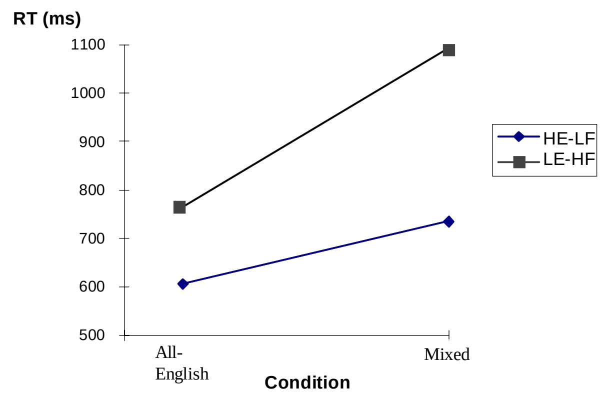

Figure 3. A comparison of two types of oppositely balanced homographs (HE-LF vs. LE-HF) and the effect on the time to recognize them as English words in the two different test conditions.

The individual subject means for the two types of stimuli were submitted to a mixed ANOVA. As before, context (All English or Mixed) was a between-subjects variable with Stimulus Type (HE-LF, LE-HF) a within-subjects variable. The analysis was conducted on the data from 19 participants, as one of the participants in the Mixed condition responded incorrectly to all of the LE-HF stimuli. The analysis revealed a main effect of Context, $F(1,17) = 15.43$, $p < .01$. The main effect of Stimulus Type was significant $F(1,17) = 32.5$, $p < .001$. Crucially, the interaction of Context(All-English, Mixed) X Stimulus Type(LE-HF, HE-LF) was significant, $F(1,17)=4.6$, $p < .05$. An independent-lexicon model predicts no interaction, whereas, as we will see, an interactive-activation model can easily accommodate this interaction.

An interactive-activation explanation of the results

Interlexical homographs bear more than a passing resemblance to their more mundane monolingual cousins, ambiguous words. In normal language use, the multiple meanings of ambiguous words, like *pants*, *bank*, or *fire* do not interfere with one another and cause problems of understanding. Generally, only one of the many possible meanings is perceived at all. The contextually irrelevant meanings are usually suppressed before they lead to any confusion (Gernsbacher, 1990). Similarly, only one meaning of interlexical homographs is perceived in a given language context. In French & Ohnesorge (1995), we suggested that this argues for an interactive-activation model in which the two language-dependent interpretations of an interlexical homograph compete in a winner-takes-all competition. We will continue this reasoning to explain the results of the above experiments in an interactive-activation framework. The model that we are suggesting is a standard bilingual interactivation-model (BIA) of the type proposed by Grainger (1992). One does not have to agree with all of the assumptions of Grainger's model (for example, his use of "language" nodes is controversial), to accept the general premises of this type of model as described in McClelland & Rumelhart (1981).

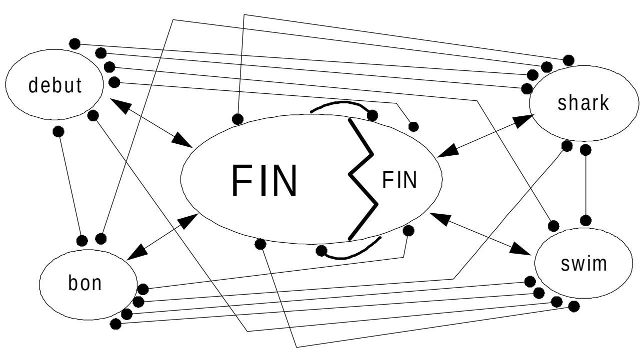

Figure 4. A section of an interactive-activation network used to explain the results of Experiments Nos. 1 and 2.

We will start by considering the second of the two experiments and attempt to answer the following questions: In the Mixed condition, why is it relatively harder to recognize homographs as being words in English than it is to recognize non-homograph (i.e., "normal") English words as being words in English? And, specifically, why are LE-HF homographs more adversely affected than HE-LF homographs in this condition?

The easiest way to understand the explanation to these questions is to refer to the drawing in Figure 4. Consider the LE-HF homograph *fin* (= "end" in French). In the winner-takes-all view of competition between ambiguous words, we have "two" competing lexical items, which we will write as $fin_{ENGLISH}$ (the vertical appendage on a shark's back) and fin_{FRENCH} (the word which appears at the end of old French movies). The latter has a considerably higher printed-word frequency in French than the former does in English, even though the English word is by no means rare. When bilingual participants are in an All-English situation in which no French items appear and they see the letter string FIN, there is virtually no competing activation from fin_{FRENCH}. The word is quickly perceived as an English word and they press the appropriate key on the keyboard. Now consider the Mixed condition. When a bilingual participant in this condition sees the word FIN, both $fin_{ENGLISH}$ and fin_{FRENCH} will receive activation and will compete for perceptual priority. But, of the two competing inhibitions, the one emanating from the more highly active component (in this case, fin_{FRENCH}, because of its higher printed-word frequency than $fin_{ENGLISH}$) is most likely to win. Assuming that only a single interpretation of any word is permitted at a given time, it follows that, before the participant can perceive FIN as an *English* word, the competing activation from fin_{FRENCH} must be overcome. The greater the competition from French, the longer the model predicts it will take to recognize a homograph as an English word. This is precisely what our data shows. For homographs whose English component has a high printed-word frequency and a French component with a low printed-word frequency (HE-LF homographs), it takes 131 ms longer in the Mixed condition than in the All-English condition to recognize that these homographs are words in English. On the other hand, for homographs with a low-frequency English component and a high-frequency French component (LE-HF), moving to the Mixed condition causes an corresponding increase of 437 ms. In other words, the interference from the French component, preventing the recognition of the homograph as an English word, is considerably more severe for LE-HF homographs than for HE-LF ones. For medium-frequency English/medium-frequency French homographs (not shown), the increase (162 ms) falls between the increases found for HE-LF and LE-HF homographs.

The explanation of the disappearance of priming also follows in a relatively straightforward manner from the interactive-activation model pictured in Figure 4. An example will clarify this. Consider the target word *shark*, which, in the All-English condition is strongly primed by *fin*. But in the Mixed condition, activation will also be sent to fin_{FRENCH}, which will inhibit its homographic English counterpart, $fin_{ENGLISH}$. This is the same inhibitory effect that caused FIN to be recognized as an English word more slowly in the Mixed condition than in the All-English condition. As a consequence of this inhibition from fin_{FRENCH}, $fin_{ENGLISH}$ will be less active in the Mixed condition than in the All-English condition (or, equivalently, its rise time to maximum activation will occur more slowly). In both cases, the spread of activation to *shark* in the Mixed condition will either be less (or later) than in the All-English condition. The predicted result is therefore that the priming of *shark* by *fin* will be significantly reduced in the Mixed condition compared to the All-English condition. As before, this corresponds precisely to our data.

Summary and Conclusion

We have presented the results of two experiments, one involving the recognition of interlexical homographs and the other involving the priming of target words by interlexical homographs, whose results would seem to strongly support an interactive-activation model of bilingual memory. It would seem that any model that does not incorporate, at the very least, mechanisms of spreading activation, excitation and inhibition among its constituent items would have a great deal of difficulty explaining the results of these two experiments. We believe that these experiments help to establish the validity of interactive-activation models of bilingual memory. At the same time, these experiments cast serious doubt on any independent-access, dual-lexicon approach of bilingual memory.

Acknowledgments

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