Using non-cognate interlexical homographs to study bilingual memory organization

Robert M. French
Center for Research on Concepts and Cognition
Indiana University
Bloomington, IN 47408
french@cogsci.indiana.edu

Clark Ohnesorge
Department of Psychology
University of Wisconsin
Madison, WI 53706
sansouci@macc.wisc.edu

Abstract

Non-cognate French-English homographs, such as *pain, four, main,* etc., are used to study the organization of bilingual memory. Bilingual lexical access is initially shown to be compatible with a parallel search through independent lexicons, where the search speed through each lexicon depends on the level of activation of the associated language. Particular attention is paid to reaction times to "unbalanced" homographs, i.e., homographs with a high frequency in one language and a low frequency in the other. It is claimed that the independent dual-lexicon model is functionally equivalent to an activation-based competitive-access model that can be used to account for priming data that the dual-lexicon model has difficulty handling.

Introduction

Is bilingual memory organized in distinct lexicons corresponding to each language or, rather is it organized in a more homogeneous fashion, comparable to monolingual memory except with twice as many words? A "separate storage" dual-lexicon model has a certain intuitive appeal, in particular, because proficient bilinguals will, in general, report little inter-lexical interference. However, numerous studies of monolingual memory involving priming by ambiguous words (Posner, 1978; Swinney, 1979; etc.) seem to cast doubt on intuitive notions of contextual modularity. For example, the word "bank" in a financial context will facilitate words like "money," "robbery", and "teller. However, words outside of the currently active context, like "river," are also primed. The existence of extra-contextual facilitation within a single language might mean that a similar phenomenon occurs between languages, where the "context" is the currently active language.

In the monolingual case, it appears that activation initially spreads along the pathways emanating from the "prime" (e.g., "bank") to *all* associatively and semantically related lexical items. Then, in a second phase, the meanings that are inappropriate to the currently active context are suppressed (Gernsbacher, 1990, 1991). In light of these findings, it would seem reasonable to ask whether the same thing might be occurring in bilingual memory. In other words, if bilingual memory were organized as monolingual memory seems to be, activation would initially spread to related lexical items in both languages and then those items not in the currently active language context would be inhibited. Evidence for this type of memory model comes largely from interlexical priming studies. Numerous studies over the years (Kolers 1966; Meyer & Ruddy, 1974; Beauvillain & Grainger, 1987; Altarriba, 1992; etc.) have demonstrated cross-lingual priming effects.

On the other hand, there have been a number of studies (Grosjean, 1982, 1989; Grosjean & Soares, 1986; Macnamara & Kushnir, 1971; Gerard & Scarborough, 1989; etc.) that seem to support a more compartmentalized language-specific view of bilingual language organization. And finally, a recent study (Neumann, McCloskey, & Felio, 1994) seems to show that inter-lingual excitatory priming disappears whereas inhibitory priming does not.

The present paper provides a tentative account for these seemingly divergent results.

Non-cognate bilingual homographs

We conducted a lexical-access experiment using adult French-English bilinguals. Since much work has been done with monolinguals using homographs to investigate cross-contextual priming, we decided to use bilingual (French/English) homographs in a similar manner. (Homographs are words like "bank" that have one meaning in a one context and a different meaning in another.) In our study, "context" refers to an entire language, rather than a situation within a single language.

It was important to select *non-cognate* bilingual homographs. The word *table*, for example, exists in both French and English, but it means essentially the same thing in both languages. We wanted only ordinary words that could be read in both languages, but whose meanings were completely different in their respective languages. These were words such as *fin, pain, main, store, four, once, bride, pour, stage, grave*, etc.

Gerard & Scarborough (1989) used non-cognate Spanish-English homographs to support the hypothesis that "lexical information is represented in language-specific lexicons and that word recognition requires searching the language-appropriate lexicon." They used the notion that the log-frequency of a word in the printed language (Scarborough, D., Cortese, C., & Scarborough, H., 1977; McCann, Besner, & Davelaar, 1988) is a consistent predictor of the time required to recognize that word. They considered non-cognate bilingual homographs, such as *red* ("net" in Spanish), that had a high frequency in one language and a lower frequency in the other. Spanish-English bilinguals were asked to look for words in a list of words/nonwords in a single target language. Mixed into the single-language list of words were the non-cognate bilingual homographs. The authors reasoned that "if recognition depends on lexical-retrieval processes shared at least in part by both languages (i.e., common encoding processes and access to common lexical entries), then homographic-non-cognate latencies may depend on the overall familiarity (overall frequency of usage) of these spelling patterns in both languages" rather than the frequency of use in the currently active language.

Their results clearly show that word frequency in the currently active language — and not the overall frequency of usage in both languages — predicts homograph recognition time, thus lending support to the language-specific dual-lexicon hypothesis.

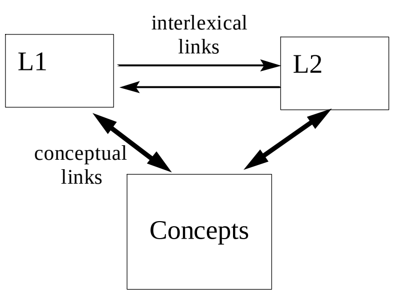

Figure 1. A hierarchical model of bilingual memory (From Kroll & Stewart, 1990)

By contrast, studies in which targets were primed by non-cognate bilingual homographs indicate that the priming effects are not restricted to one lexicon. (Note: Gerard & Scarborough (1989) were not considering reaction times to *primed* lexical items.) But cross-language priming should not occur, or only occur very weakly, if there were independent language-specific lexicons. Altarriba (1992) has suggested that in some of these studies inter-language priming can be attributed to the use of a long interval between the presentation of the prime in one language and the subsequent presentation of the target in the second language. She suggested that even a 300 ms prime-target interval "might have been long enough to permit the translation of the prime or the use of other strategies on the part of the subjects." In other words, if bilingual memory were organized as in Figure 1 (Kroll & Stewart, 1990), a 300 ms prime-target delay could be long enough to permit translation of the prime via the concept area.

However, even after taking Altarriba's criticism into account, there are still studies in which cross-language lexical priming was observed. In particular, Beauvillain & Grainger (1987) presented the prime for only 100 ms with a 50 ms delay before the target presentation, i.e. well below the 300 ms conceptual translation threshold referred to by Altarriba

We suggest that lexical access of unprimed target words can be modeled by a parallel search of two independent lexicons where the speed of the search through each lexicon is a function of the activation of the corresponding language. Since a model with two separate lexicons should have difficulty accounting for inter-lexical priming data, we show that this kind of model is functionally equivalent, at least in the case of lexical access to unprimed target words, to an activation-based competitive-access model of lexical access. This latter model would seem better at accounting for inter-lexical priming effects.

Experimental design

Participants

The participants were 48 bilingual males and females recruited from the University and surrounding community. Virtually all were in daily contact with both French and English and judged themselves highly fluent in both French and English. The pool was drawn up of professors and graduate students in the French department, translators, and native French speakers having lived for many years in the US, etc. Twenty-five of the subjects were native French speakers. The 24 participants for each of the two conditions of the experiment were randomly selected.

Stimuli

The critical stimuli were 45 non-cognate bilingual homographs (i.e., words like *pain, main, but, son, or, pour, as, seize,* etc.). All of the homographs chosen had completely different meanings in French and English. The frequency of appearance of these words in printed French ranged from 1 to 10,198 occurrences per million words (Baudot, 1992). In printed English, they ranged from 0 to 7250 occurrences per million words (Kucera & Francis, 1967). The remainder of the stimulus set, the "filler" stimuli used to set the context, consisted of a total of 645 letter strings: 300 French words, 300 French-based nonwords, and, to balance the 45 homographs, 45 nonword-homographs produced by altering one letter of a set of bilingual cognate homographs (e.g., "silence" → "sirence"). In other words, there were altogether 345

French words and 345 nonwords. All stimuli were presented in all capital letters in a 24-point Chicago font.

Procedure

The experiment consisted of two conditions, an All-French condition, where the participants saw only French words/nonwords, and a Mixed condition, where they saw a mixture of half French and half English words/nonwords.

All-French Condition Participants did the experiment individually in 45-minute sessions in which they responded to 450 experimental trials. The experiment was run on PsyScope (Cohen, J. *et al*, 1993) on a Power Macintosh computer. The instructions were written in French and were read from the computer screen at the beginning of the experiment. Participants were seated approximately 20” in front of the computer monitor. The instructions indicated that they would see letter strings and were to classify them as words (if they were real words in French or in English) or nonwords. Included in the list of lexical items was the critical set of bilingual non-cognate homographs, such as, *fin, pain, main, son, four*, etc. Reaction time to these homographs was the critical dependent variable. Of particular interest were “unbalanced homographs” whose printed-word frequencies were high in one language and low in the other. After reading the instructions, the participants initiated a block of 40 practice trials. Upon completion of the practice block, they began the experimental trials. On each trial a letter string was presented and remained on the screen until a response was made. After a 500 ms interval the next stimulus was presented. Feedback, in the form of a beep, indicated when a word/nonword had been misclassified. Participants responded to a total of 450 letter strings: 180 French words, 180 French-based nonwords, 45 cognate-based nonwords, and the 45 critical homographs.

Mixed Condition Identical to the All-French condition, except that the “filler” stimuli consisted of an equal mixture of French and English words and nonwords. The word/nonword lexical decision task was the same as in the All-French condition. We were particularly interested in the times required to recognize homographs — and, especially, “unbalanced” homographs — in this condition compared to the All-French condition.

Summary of Results

The All-French condition of the experiment confirmed the conclusions of Gerard & Scarborough (1989) — namely, that bilinguals’ reaction time to non-cognate interlexical homographs is better predicted by their log-frequency in the currently active language rather than their summed log-frequency over both languages. In the All-French context, we found the homographs’ French log-frequency was a better predictor of recognition time ($r(43)=0.55$, $p < 0.01$) than the summed log-frequency ($r(43) = 0.41$, $p < .01$). It is to be noted that English log-frequency of the homographs did not predict reaction times in the All-French condition ($r(43) = 0.1$).

In the Mixed condition participants were exposed to equal proportions of French and English words/nonwords. The key results involved two sets of “unbalanced” homographs, i.e., homographs whose printed-word frequencies were significantly different in the two languages. The first subset consisted of 6 homographs with a low frequency in French and a high frequency in English (mean log-frequency in French = 1.1, $\sigma = 0.2$; mean log-frequency in English = 2.8, $\sigma = 0.7$). We called these LF/HE homographs. The second subset consisted of 10 homographs with a high frequency in French and a low frequency in English (mean log-frequency in French = 2.4, $\sigma = 0.4$; mean log-frequency in English = 1.0, $\sigma = 0.27$). We called these HF/LE homographs. High frequency in both languages was defined as belonging to 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; and Baudot, 1992).

We used a 2(All-French, Mixed) x 2(LF/HE, HF/LE) design for the experiment. The data were submitted to a 2x2 mixed ANOVA with the Context variable having two levels, All-French and Mixed, and the Homograph-type variable including two different types of homographs, LF/HE and HF/LE. Context was a between-subjects variable and Homograph-type was a within-subjects variable.

Both main effects and their interaction were significant. Our major focus was on the Context x Homograph-type interaction ($F(1,46) = 21$, $p < .01$) and its derivative simple effects — namely:

- For LF/HE homographs, a significant decrease in mean reaction time (from 912 to 710 ms; $F(1,46) = 11.5$; $p < .01$) when the context is changed from All-French to Mixed;
- For HF/LE homographs, no significant difference in reaction time between the Mixed context from the All-French context ($F(1,46) = 0.4$, $p > 0.1$).

These reaction-time results are given in Figure 2 below.

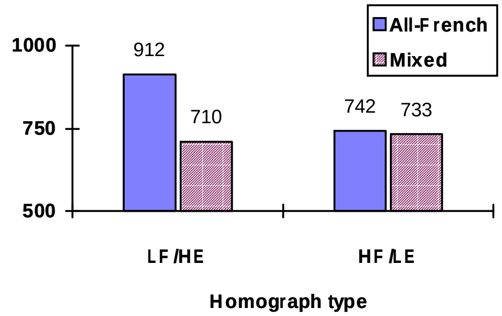

Figure 2. Changes in mean reaction time for the two different types of "unbalanced" homographs in the All-French context versus the Mixed context.

Explanation of the results

We suggest that these data are compatible with a model based on a differentially active, parallel search through two independent lexicons. We then argue this model is itself compatible with a "single-lexicon" activation-based competition model of lexical access.

In general, only one of a bilingual's lexicons is active. But, under some circumstances, people do fully activate both lexicons — in particular, when translating, especially simultaneously, from one language to another.

Let us start by considering the ramifications of a dual-lexicon model with parallel search. In the All-French condition, we attempted to activate only French by presenting participants with words and nonwords exclusively in French. English would, however, have remained somewhat active, however, if only because the lexical decision task required identification of words in French OR in English. Participants would therefore have been primed to see words in English, thereby activating their English lexicon. In the Mixed condition we attempted to fully activate both of the participants' lexicons.

Parallel search through both lexicons, with the speed of the "search demons" in each lexicon depending on how active that lexicon is (Figure 3), would predict the following differences in recognition times as one goes from the All-French to the Mixed contexts:

- faster reaction times for LF/HE homographs;
- very little change in reaction times for HF/LE homographs.

Figure 2 indicates that the reaction-time data for unbalanced homographs agrees with the predictions of this model.

An example will help explain why reaction times improve for LF/HE homographs (Figure 3) when going from the All-French context to the Mixed context. In the All-French context, the French-lexicon "search demon" will reach "ride" (= "wrinkle" in French) before its weakly active, thus slower-moving English-lexicon competitor. In the Mixed context, however, both French and English lexicons are fully active and, as a result, the search speed of the two search demons will be about the same. Because the English log-frequency for "ride" is higher than the French log-frequency, the English search demon will now arrive at "ride" before the French-lexicon search demon. Since the distance traveled by the fully-active English demon through the English lexicon in the Mixed context is less than the distance traveled by the fully-active French demon through the French lexicon in the All-French context, the recognition time for "ride" will be shorter in the Mixed Context condition.

Similarly, this "search-demon" metaphor helps explain why reaction times to HF/LE homographs remain essentially unchanged when going from the All-French to the Mixed context (Figure 4). Consider the HF/LE homograph "champ" (= "field" in French). In both the All-French context and in the Mixed context, the French lexicon is fully active. Thus, in both cases, the French "search demon" will beat the English demon to the lexical item "champ".

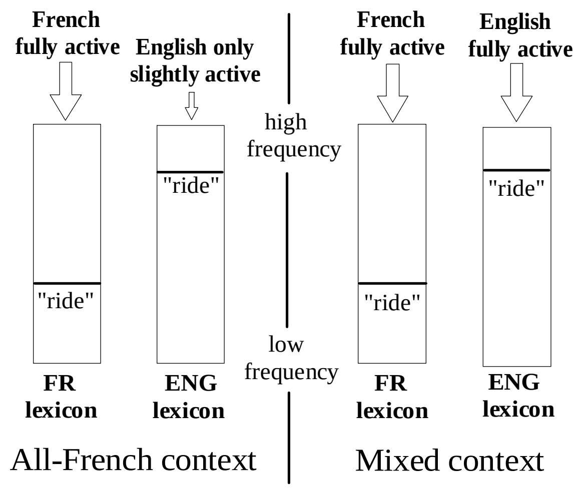

Figure 3. Dual-lexicon, parallel-search model. Recognition time decreases for a HE/LF homograph in going from All-French to Mixed context.

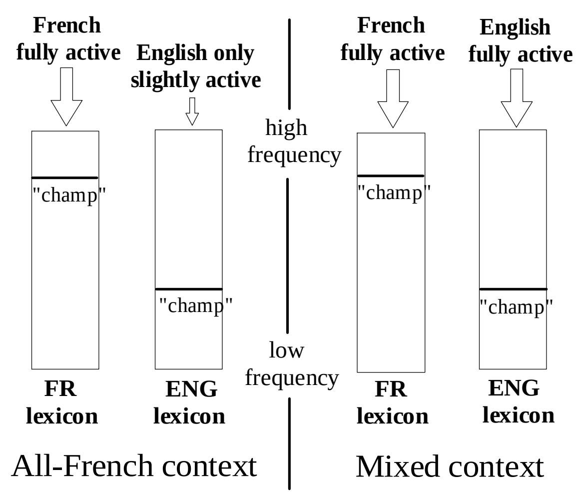

Figure 4. Dual-lexicon, parallel-search model. Recognition time remains the same for LE/HF homograph in going from All-French to Mixed context.

Another way of describing this model is by saying that word recognition time is predicted by:

$$\max(f_{FR}A_{FR}, f_{ENG}A_{ENG})$$

where

f_{FR} is the French log-frequency of the word;
A_{FR} is the activation of the French context;

f_{ENG} is the English log-frequency of the word;
A_{ENG} is the activation of the English context.

Thus, in the All-French context A_{ENG} will be low, and reaction times will be predicted largely by French homograph frequency. This was shown in the All-French condition to be the case. In the Mixed context, A_{ENG} will be approximately equal to A_{FR}, since both the English and French lexicons are assumed to be fully active. In this case, the maximum between f_{FR} and f_{ENG} should predict reaction time better than either French or English log-frequencies alone. The data tend to support this prediction. In the Mixed context, there was a correlation of r = 0.62 between mean reaction time and the maximum French or English log-frequencies for the homographs. This compared to r = 0.51 for French log-frequencies alone, and r = 0.42 for English log-frequencies.

Finally, this model explains why, even in the All-French context, certain extreme LF/HE homographs will still be recognized by some bilinguals as English words. This is because, even though the activation of English (A_{ENG}) may be low, it is not completely zero; in addition, f_{ENG} is very high. Consequently, for extreme LF/HE homographs, the product $f_{ENG}A_{ENG}$ may still exceed $f_{FR}A_{FR}$ and the bilingual will recognize the homograph as a word in English. The data supported this conclusion. The LF/HE homograph *if* (= "yew tree" in French) had, by far, the lowest French log-frequency of all LF/HE homographs. The mean reaction times for LF/HE homographs in the All-French context was 912 ms (σ=51). And yet, the mean reaction time in the All-French context for *if*, rather than being slower than the mean, as would have been expected, was, in fact, 0.8 SD *faster* than the mean.

An activation-based competition model of bilingual memory

The dual-lexicon, differentially active, parallel search model of bilingual accounts for our unprimed lexical-access data. However, the inter-lexical priming data reported by Beauvillain & Grainger (1987) would be harder to explain with this model. We suggest that an activation-based competition model might be more appropriate to explain both unprimed and primed lexical access data. This activation-based model is consistent with the predictor, the $\max(f_{FR}A_{FR}, f_{ENG}A_{ENG})$, described in the previous section.

The key intuition is as follows. Recognition time for a word in a monolingual lexicon is predicted by the printed-word log-frequency of that word. In approximate Hebbian terms (Hebb, 1949), each new encounter with the word would cause a (logarithmic) recruitment of new cells to the cell-assembly associated with the word. In the case of a bilingual, the same type of recruitment would presumably go on, except that each "recruit" would be associated with the language context in which it was recruited. Consider the word "ride", which means "wrinkle" in French. Each time bilinguals see the word "ride" in English, a small number of units, each associated with the "English" context, are added to the representation of RIDE. Similarly, every time the word "ride" is encountered in a French context (which is considerably rarer than in English), a small number of units, each associated with the "French" context, are added to the representation of RIDE. The overall picture might look something like Figure 5.

In normal language use, only one of the multiple meanings of ambiguous words is perceived. The contextually irrelevant meanings are suppressed (Gernsbacher, 1990). In a similar fashion, only one meaning of a bilingual homograph is perceived at a given time. This argues for a model in which the two language-dependent interpretations compete in a winner-takes-all competition. In addition, the inhibitory mechanism suggested by Neumann, McCloskey, & Felio (1994) supports this inter-lexical competitive mechanism whereby the more active meaning suppresses the less active interpretation of a particular homograph.

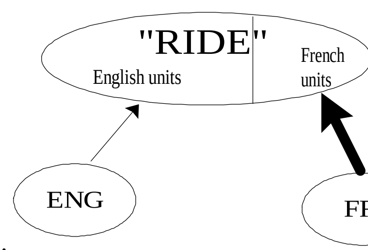

Figure 5. An activation-based competitive-access model of bilingual memory in the All-French context

In this model, each group of units will be differentially activated according to the amount of activation coming from the languages with which they are associated. If the French context is fully active and the English context is only weakly active (as in the All-French context), the set of "French" units comprising "ride" will most likely have more overall activation than the larger, but less active set of English units making up the representation. The more active French units will therefore inhibit the English units and, as a result, "ride" will be perceived in its French meaning of "wrinkle." (This is just another way of saying that when $f_{FR}A_{FR}$ exceeds $f_{ENG}A_{ENG}$, the former will win the competition and determine the activation of the entire representation. This is what occurs in the parallel search model.)

The advantage of this activation-based description of bilingual memory is that it fits into an established framework of automatic spreading activation in which interlexical priming could be more easily explained. Just as activation in a monolingual English lexicon initially spreads automatically from "bank" to all of its related items in a context-independent manner, the activation-based description of bilingual lexical access could be used to explain the type of cross-lingual priming reported by Beauvillain & Grainger (1987).

Conclusion

We have attempted to show how a simple dual-lexicon model using differentially active, parallel search can account for word recognition-time data in bilinguals. It is claimed that two factors — word log-frequency and the degree of language activation — predict word recognition times. Recognition times for non-cognate bilingual homographs, such as *pain, pour, main, as,* etc. were used to study the effect of modifying the language context from an essentially monolingual one to a mixed half-French/half-English context. Finally, we suggest that an activation-based, competition model is functionally equivalent to the dual-lexicon model and would seem well suited to account for both recognition times for both unprimed stimuli as well as inter-lexically primed stimuli.

Acknowledgments

The authors would like to thank Jim Friedrich, Morton Ann Gernsbacher, Virginia Marchman, and John Theios for their contribution to this research. We would also like to especially thank all the French-English bilinguals who took part in this research.

Bibliography

Altarriba, J., (1992). The Representation of Translation Equivalents in Bilingual Memory. In *Cognitive Processing in Bilinguals*. J. Harris (ed.). Amsterdam: Elsevier.

Beauvillain, C. & Grainger, J. (1987) Accessing Interlexical Homographs: Some Limitations of a Language-selective access. *Journal of Memory and Language*, 26, 658-672.

Cohen, J., MacWhinney, B., Flatt, M., & Provost, J. (1993). PsyScope: A new graphic interactive environment for designing psychology experiments. *Behavioral Research Methods, Instruments & Computers*, **25**(2), 257-271.

Gerard, L. & Scarborough, D. (1989) Language-specific lexical access of homographs by bilinguals. *Journal of Experimental Psychology: Learning, Memory, and Cognition*. Vol. 15, No. 2, 305-315.

Gernsbacher, M., (1990) *Language Comprehension and Structure Building*. Hillsdale, N.J.: Lawrence Erlbaum.

Gernsbacher, M. (1991) Cognitive processes and mechanisms in language comprehension: The structure building framework. In *The Psychology of Learning and Motivation*. Vol. 24, Bower, G. (ed.), New York, NY: Academic Press.

Grosjean, F. (1982) *Life With Two Languages*. Cambridge, MA: Harvard University Press. Ch. 5, 228-288.

Grosjean, F. (1989). Neurolinguists, Beware! The Bilingual is Not Two Monolinguals in One Person. *Brain and Language*, **36**, 3-15.

Grosjean & Soares, 1986 "Processing Mixed Language: Some Preliminary Findings" In *Language Processing in Bilinguals*. Jyotsna Void (ed.) Hillsdale, NJ: Lawrence Erlbaum, Inc

Hebb, D. O. (1949) *The Organization of Behavior*. New York, NY: Wiley & Sons.

Kroll, J. & Stewart, E. (1990). Concept mediation in bilingual translation. Paper presented at the 31st Annual Meeting of the Psychonomic Society, New Orleans.

Kolers, P. (1966). Interlingual Facilitation of Short-term Memory. *Journal of Verbal Learning and Verbal Behavior*. **5**, 314-319.

Kucera, H. & Francis, W., (1957) *Computation Analysis of Present-day American English*. Providence, RI: Brown University Press.

McCann, R., Besner, D., & Davelaar, E. (1988) Word Recognition and Identification: Do Word-frequency Effects Reflect Lexical Access? *Journal of Experimental Psychology: Human Perception and Performance*. **14**(4) 693-706.

Macnamara, J. & Kushnir, S. (1971). Linguistic Independence of Bilinguals: The Input Switch. *Journal of Verbal Learning and Verbal Behavior*, **10**, 480-487.

Meyer, D. & Ruddy, M. (1974). Bilingual word-recognition: Organization and retrieval of alternate lexical codes. Paper presented at the meeting of the Eastern Psychological Association, Philadelphia.

Neumann E., McCloskey, M., & Felio, A. (1994). Primed lexical decision tasks: Cross-language positive priming disappears, negative priming doesn't. NIMH, Laboratory of Socio-environmental studies Tech. Report.

Scarborough, D., Cortese, C., & Scarborough, H. (1977) Frequency and repetition effects in lexical memory. *Journal of Experimental Psychology: Human Perception and Performance*, 3, 1-17.

Swinney, D. (1979) Lexical access during sentence comprehension: (Re)consideration of context effects. *Journal of Verbal Learning and Verbal Behavior*. **18**, 645-659.