Activation of Russian and English Cohorts During Bilingual Spoken Word Recognition

Viorica Marian (vm22@cornell.edu)
Michael Spivey (mjs41@cornell.edu)
Department of Psychology
Cornell University
Ithaca, NY 14853

Abstract

The traditional language switch hypothesis, according to which bilinguals can selectively activate and deactivate either language, has been repeatedly challenged in recent studies. In particular, an eyetracking experiment investigating spoken language processing suggests that bilinguals maintain both languages active in parallel even during monolingual input. The present study extends this finding to circumstances exhibiting between-language competition, within-language competition, or both. In this experiment, we find evidence for lexical items in the first language interfering with processing of the second language. We find that, in addition to competing activation between languages, bilinguals (like monolinguals) encounter competition within languages. Moreover, the results suggest that when simultaneous competition is encountered from items in both languages, within-language competition may be stronger than between-language competition. It appears that a bilingual's irrelevant language continues to be processed even when not actively used. However, this phenomenon is considerably influenced by language mode, even when such variables as word frequency, phonetic overlap, and language preference are taken into account.

Introduction

With the majority of the world's population speaking more than one language (Romaine, 1995), studying bilingualism and polyglotism can provide valuable insights into human cognition and language. The capability of one cognitive system to successfully manage two languages is striking. Do bilinguals use the two languages independently, alternating between them by turning them on and off, or do they constantly keep both languages active and process the two in parallel at all times? The traditional language switch hypothesis, according to which bilinguals are able to selectively activate and deactivate their two languages (Gerard and Scarborough, 1989; McNamara & Kushnir, 1971), has been challenged by a number of recent findings. Parallel activation has been inferred from early studies using the bilingual Stroop task (Chen & Ho, 1986; Preston & Lambert, 1969), from studies using code-switching (Grainger, 1993, Grainger & Dijkstra, 1992; Li, 1996; Soares & Grosjean, 1984), interlingual homographs (Dijkstra, van Jaarsveld, & ten Brinke, 1998; Dijkstra, Timmermans, and Schriefers, 1997), and cognates (DeGroot & Nas, 1991; Kroll & Stewart, 1994). More recently, evidence for parallel activation comes from masked orthographic priming (Bijeljac-Babic, Biardeau, & Grainger, 1997) and interlingual neighbors (van Heuven, Dijkstra, & Grainger, in press). Attempts to extend the hypothesis of generalized lexical access from the visual to the phonological domain using code-switching were also encouraging (Nas, 1983; Doctor & Klein, 1992).

However, the most compelling evidence supporting automatic activation of both lexicons during monolingual input comes from research investigating spoken language processing in bilinguals using eye-tracking (Spivey & Marian, 1999). The eye-tracking technique, merging input from both the visual and auditory modalities, allows one to index the activation of a second language non-linguistically. It allows testing processing of both languages without compromising a monolingual mode, something that is otherwise difficult. Spivey and Marian (1999) presented subjects with a visual display consisting of four objects and asked them to manipulate a target object. The onset of the name of the target object bore phonetic similarity to the name of one of the other objects in the other language. For example, when instructed "Poloji *marku* nije krestika" ("Put the stamp below the cross"), the visual display in front of the subject contained, among other objects, a *marker*, the name of which shares several phonemes with "marka," the Russian word for stamp. It was found that, while processing the target word "marka," Russian-English bilinguals made eye movements to the between-language competitor "marker," thus suggesting that lexical items in both languages were activated simultaneously, even though only one language was being used.

While this work shows cross-linguistic activation in bilingual spoken language processing, it leaves many questions unanswered. It does not, for example, indicate what happens during bilingual language processing when competition takes place in more realistic visual context. In every-day environments, while processing spoken language, bilinguals are surrounded by a multitude of objects, some of them do indeed compete cross-linguistically, while others compete within the same language, and, finally, in many cases the competition may come simultaneously from both languages. What happens under these circumstances of simultaneous competition from both languages?

A second question arises from the fact that Spivey and Marian (1999) found an asymmetry in their results, with stronger competition from the second language into the first language. We hypothesized that the asymmetry may have been due to the slight preference for English among the bilinguals in that study, or to the subjects' current immersion in an English-speaking environment. We tested both of these hypotheses in the present study, by manipulating the strength of the language mode and by considering language preference as a variable. We aimed to replicate the between-language competition phenomenon observed by Spivey and Marian (1999), while trying to instill a better Russian language mode to examine if competition from the first into the second language can occur.

Finally, we wanted to see if bilinguals would show within-language competition from items whose name bore phonetic overlap in the same language, as did English monolinguals (Allopenna, Magnuson, & Tanenhaus, 1998; Spivey-Knowlton, 1996), thus extending the within-language competition phenomenon to the bilingual domain. In sum, the present study followed three goals: (1) replicate the robustness of the between-language activation phenomenon observed by Spivey and Marian (1999), (2) investigate within-language parallel activation in bilinguals, and, most importantly, (3) investigate language processing in the case of simultaneous competition from both languages. We also took into account such variables as word frequency, amount of phonetic overlap, language preference, and language mode.

Method

Participants

Fifteen Russian-English bilinguals participated in the study, 5 males and 10 females. All were students at Cornell University, their mean age was 22.04 years (SD=3.77). All were Russian-English bilinguals, born in former Soviet Union, who immigrated to the United States at the mean age of 15.62 years (SD=3.65). Six participants indicated that Russian was their preferred language of use at the time when the study was conducted, five participants indicated that English was their preferred language of use, and four indicated no language preference. Informed consent was obtained and participants' rights were protected. All participants were paid for their participation.

Apparatus

A headband-mounted ISCAN eyetracker was used to record the subjects eye movements during the experiment. A scene camera, yoked with the view of the tracked eye, provided an image to the subject's field of view. A second camera, focused on the center of the pupil and the corneal reflection, provided an infrared image of the left eye. Gaze position was indicated by crosshairs superimposed over the image generated by the scene camera. The output was recorded onto a Hi8 VCR with frame-by-frame playback.

All the instructions were pre-recorded by a fluent Russian-English bilingual speaker who acquired both languages in early childhood and had no noticeable accent in either language. SoundEdit was used to record and play the video record for data analysis. the speech files, and the audio record was synchronized with

Design and Stimuli

All participants were tested in two parts, a Russian part and an English part, with order counterbalanced across subjects. Each part consisted of 20 trials, equally distributed across four conditions. In the no-competition condition, of the four objects presented in the display one was the target object and three were control filler objects. The target object was the object actively named in the experiment. The filler objects were objects whose name did not overlap with the name of the target object in either language. This first condition served as the baseline for all analyses.

In the between-language competition condition, of the four objects presented in the display, one was the target object, one was the between-language competitor, and two were filler objects. The between-language competitor was an object whose name in the other language carried phonemic overlap with the name of the target object. For example, during the English part, if "speaker" was the target object, then "speachki," the Russian word for "matches," was the between-language competitor. The name of the between-language competitor was never spoken in either language during the entire experiment.

In the within-language competitor condition, of the four objects presented in the display, one was the target object, one was the within-language competitor, and two were filler objects. The within-language competitor was the object whose name carried phonemic similarity to the target object in the same language. For example, during the English part, if the target object was a "speaker," then the within-language competitor was a "spear." Similarly, in the Russian part, if the target object was "speachki" (matches), then the within-language competitor was "speatsy" (knitting needles). The name of the within-language competitor was also never spoken during the entire experiment.

Finally, in the fourth condition, of the four objects presented in the display, one was a target object, one was a between-language competitor, one was a within-language competitor, and one was a filler object. This fourth condition allowed testing a situation in which simultaneous between-language and within-language competitions take place. The four conditions were intermixed throughout the experiment. A complete list of all target items, between-language competitors, and within-language competitors for both Russian and English can be found in Table 1.

To avoid potential confounds, we considered in each trial such variables as the physical similarity of the items, the word frequency in the two languages, and the amount of phonemic overlap. During the experiment, similarities in the physical properties (size, shape, color) of a target object and one of the filler objects in the display were noticed for one Russian set (a baloon and a pear) and one English set (a greeting card and a napkin). As a result, all trials containing these sets were discarded from analyses.

To compute word frequency, we used three sources. For the English language, we used Zeno et al.'s 1995 Word Frequency Guide based on a corpus of 17,274,580 word tokens. For the Russian words, we used Lenngren's (Ed.) 1993 frequency

Table 1. English and Russian Target and Competitor Words.

Russian Target			English Competitor	Russian Competitor		
Спички	[spichki]	(Matches)	Spear	Спицы	[spitsi]	(Knitting needles)
Бусы	[boosy]	(Beaded necklace)	Book	Бубен	[buben]	(Tambourine)
Черепаха	[cherepaha]	(Turtle)	Chair	Червяк	[chervyak]	(Worm)
Марка	[marka]	(Stamp)	Marker	Марля	[marlya]	(Cheese cloth)
Баран	[baran]	(Ram)	Barbed Wire	Бархат	[barhat]	(Velvet)
Платье	[platye]	(Dress)	Plum	Плащ	[plashch]	(Raincoat)
Гайка	[gaika]	(Nut)	Gun	Галстук	[galstuk]	(Necktie)
Карта	[karta]	(Map)	Car	Картошка	[kartoshka]	(Potato)
Лак для погтей	[Lak dlea nogtei]	(Nailpolish)	Lock	Лопата	[lapata]	(Shovel)

English Target	English Competitor	Russian Competitor		
Speaker	Spear	Спички	(spichki)	Matches
Boot	Book	Бубен	(buben)	Tambourine
Shark	Shovel	Шарик	(sharik)	Balloon
Chair	Chess set	Черепаха	(cherepaha)	Turtle
Marker	Marbles	Марка	(marka)	Stamp
Barbed wire	Bark	Бархат	(barhat)	Velvet
Plug	Plum	Платье	(platye)	Dress
Gun	Gum	Гайка	(gaika)	Nut
Lock	Lobster	Лак для погтей	(Lak dlea nogtei)	Nailpolish

dictionary based on a corpus of 1,000,000 word tokens, as well as Zasorina's (Ed.) 1977 frequency dictionary based on 40,000 word tokens. In addition, we translated all the Russian words and considered the frequency of the translated words in the English language, and translated all the English words into Russian and considered the frequency of the translated words in the Russian language based on the two Russian sources. Both raw word frequency and word frequency adjusted for dispersion were considered. None of the performed analyses showed any statistically significant difference in the frequency of the target and competitor items in either language.

Phonetic overlap was analyzed based on the raw number of overlapping phonemes, as well as the proportion of word overlap across two items. T-tests were performed both across the two languages as well as for each language separately. Overlap within and between languages was considered. No significant difference was found in any of the analyses. The only marginally significant difference was observed for proportion of overlap (but not the raw number of phonemes) in the analysis of English, where overlap with the target word was higher for within-language competitors than for between-language competitors; $t=2.26$, $p<0.1$.

Procedure

Upon arrival to the lab, subjects were greeted and interacted with exclusively in the language appropriate for that part of the experiment, including the written consent form and spoken instructions. In addition, to better instill a Russian language mode, popular Russian songs were played via a tape-recorder at the beginning of the Russian session. This manipulation was done to increase the strength of the Russian mode, since Russian was a passive language in the subjects' overall environment at the time and to test whether significant competition from Russian into English can occur.

Participants were then seated at arm's length from a 61 cm by 61 cm white board set on a table. The board was divided into 9 equal squares and a black cross in the center square served as a neutral fixation point. After the eyetracker was calibrated, each participant was presented with 40 trials, 20 in each language. In each trial, subjects were asked to look at the central cross, followed by instructions to manipulate the target object. An example of verbatim instructions is "Pick up the speaker. Put the speaker below the cross" in English, and "Podnimite speachki. Polojite speachki nije krestika." ("Pick up the matches. Put the matches below the cross") in Russian. Subjects then received two filler instructions to manipulate filler objects in order to prevent them from guessing the hypothesis of the study.

Results

To test between-language competition, we compared the percentage of trials when subjects made eye movements to the between-language competitor with the percentage of trials with looks to the same square when a control filler was present. Analyses of variance were computed by subjects (F1) and by items (F2). As shown in Figure 1, combined across languages, subjects were more likely to make eye movements to the between-language competitor (16%) than to the control filler (7%); $F1(1,14)=7.22$, $p<0.02$; $F2(1,16)=3.48$, $p=0.08$. Separate by-language analyses indicated that, during English trials, subjects made eye movements to the between-language Russian

Between-Language Competition

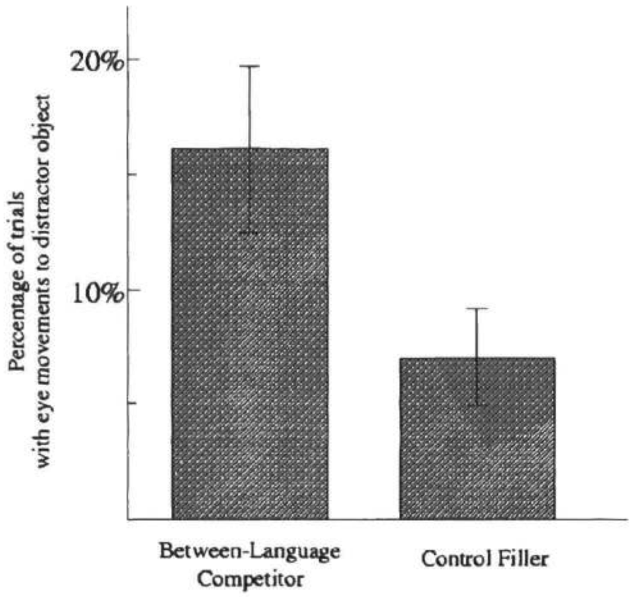

Figure 1. Mean proportion of trials where subjects looked at the between-language competitors in condition 2 compared to the filler object in the same square in condition 1.

Within-Language Competition

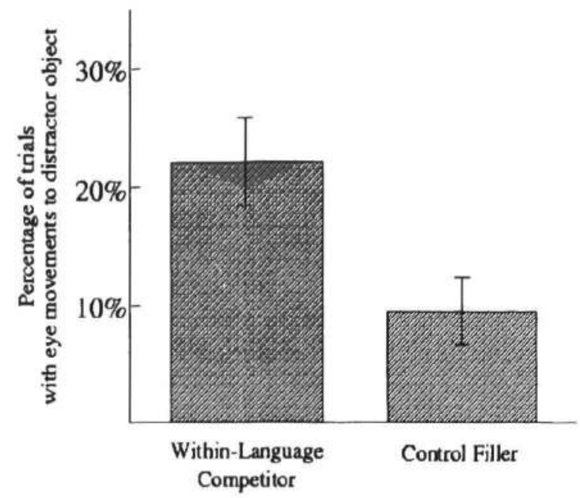

Figure 2. Mean proportion of trials where subjects looked at the within-language competitors in condition 3 compared to the filler object in the same square in condition 1.

competitor 21% of the time and to the control filler 6% of the time, $F(1,14)=12.43$, $p<0.01$; $F2(1,8)=11.85$, $p<0.01$. During Russian trials, subjects made eye movements to the between-language English competitor and the control filler, 11% and 9% of the time, respectively, $F1(1,14)=0.2$, $p>0.1$; $F2(1,8)=0.02$, $p>0.1$. This asymmetry in the results, with stronger competition from Russian items during English trials, follows the mirror reverse pattern to that observed by Spivey and Marian (1999), suggesting that manipulating the strength of the Russian language mode in the present study had a direct influence on the strength of between-language competition[1].

To test within-language competition, the proportion of trials with eye movements to the within-language competitor was compared to the proportion of trials with eye movements to the same square when a control filler was present. As shown in Figure 2, subjects looked significantly more often to the within-language competitor (21% of the time) than to the control filler (9%); $F1(1,14)= 7.6$, $p<0.02$; $F2(1,16)=3.74$, $p=0.07$. Analyses by language showed that, during English trials, subjects looked at the within-language competitor 21% of the the time and at the control filler 4% of the time; $F1(1,14)=8.33$, $p<0.02$; $F2(1,8)=4.67$, $p=0.06$. During Russian trials, subjects looked at the within-language competitor 21% of the time and at the control filler 13% of the time, $F1(1, 14)=1.34$, $p>0.1$; $F2<1$.

[1] Analyses of language preference showed no significant effect on between-language competition. A closer look revealed, however, that Russian-preferring subjects showed absolutely no interference from English into Russian. Therefore, part of the reason why English did not interfere with Russian is because only the English-preferring subjects contributed to that interference.

The results of simultaneous within-language competition and between-language competition are shown in Figure 3. Combined across both languages, subjects looked at the within-language competitor 19% of the time, compared to the control filler 9%; $F1(1,14)=6.76$, $p<0.05$; $F2(1,16)=3.58$, $p=0.08$. Subjects looked at the between-language competitor 13% of the time, compared to the control filler 7% of the time, $F1(1,14)=2.2$, $p>0.1$; $F2(1,16)=0.58$, $p>0.1$. These results suggest that, in situations of simultaneous within-language and between-language competition, the within-language competition may be stronger.

A comparison of the first half and the second half of the experiment, in order to test for order effects, did not reveal a significant difference in the patterns of competition before the language switch and after it. Within-language competition, between language competition, and simultaneous within- and between-language competition were relatively similar in the two parts.

Discussion

The present study reinforces the hypothesis of parallel activation of two languages during bilingual language processing. While the main effect of between-language competition across languages replicates the basic finding of Spivey and Marian (1999), the asymmetries in the results of by-language analyses in the two studies are in exactly opposite directions. Spivey and Marian found that competition was stronger from the second language into the first, while in the present study competition was stronger from the first language into the second. These differences can be reconciled if we consider more carefully the

Simultaneous Competition From Both Languages

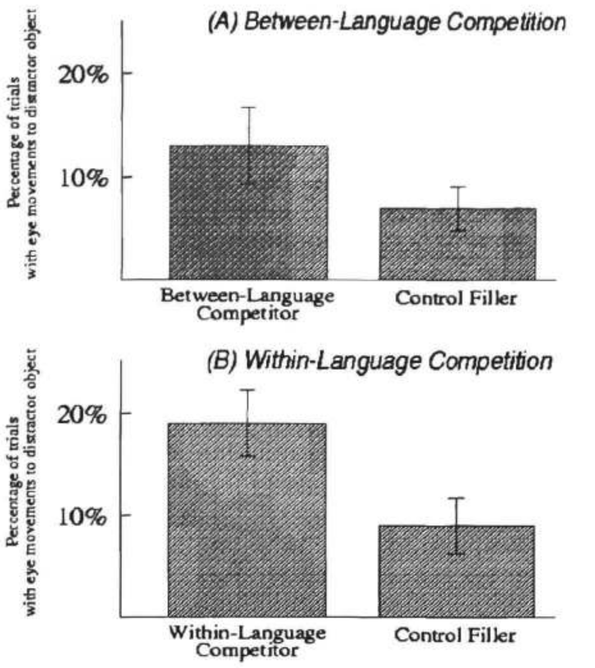

Figure 3. Mean proportion of trials in which subjects looked at the within-language competitors and at the between-language competitors in condition 4 compared to the filler objects in the same squares in condition 1.

participants' language modes in the two studies. In the Spivey and Marian study, it is likely that participants were in a stronger second-language (English) mode, since their everyday surrounding environment was predominantly English (the campus of an American University) and since efforts to instill a Russian mode were minimal. In the present study, however, the strength of the Russian language mode was manipulated by exposing subjects to Russian music that carried strong cultural and linguistic connotations. These were Russian children songs, songs from popular TV shows, and otherwise popular songs that were known to all former Soviet citizens. Subjects systematically commented on the Russian songs they heard. It is possible that such distinct cultural components were strong triggers of a Russian language mode. Thus, it appears that, when greater time and effort is put into instilling a Russian environment in the laboratory, the English session shows reliable interference from Russian. This pattern of results is consistent with the proposed role of language mode in on-line comprehension (Grosjean, in press; Grosjean, 1999; Soares & Grosjean, 1984). Apparently, as the present study suggests, subtle manipulations of the linguistic environment may alter a bilingual's language mode and dramatically influence the pattern of language processing.

Our study was the first to consider eyetracking evidence for within-language competition in bilinguals. The results suggest that, similar to monolingual English speakers, bilingual Russian-English speakers also encounter within-language lexical competition. These findings provide further support for the robustness of the within-language competition phenomenon. However, analyses by language show that this main effect was driven chiefly by within-language competition in the English language. It is worth noting, though, that, in Russian, the average frequency of the target words was about twice that of the within-language Russian competitors (depending upon the source of the frequency ratings, the respective frequencies are 41.7 (SD=52.7) (Zeno et al., 1995), 44.2 (SD=48.8) (Zasorina, 1977), and 31.9 (SD=28.6) (Lenngren, 1993) words per million for the targets, compared to 17.5 (SD=24.1), 19.9 (SD=22.9), and 21.2 (SD=25.6) words per million for the competitors, respectively). These differences, although not statistically significant, should not be completely discarded as possible factors in contributing to what might be a Type II error in analyses on within-language competition in Russian.

Finally, an investigation of simultaneous within- and between-language competition during bilingual spoken language processing suggests that competition may be stronger within than between languages. The results of the study permit us to conclude that, during spoken language processing, the interplay between visual and auditory information processing can cause bilingual listeners to encounter competition from items between their two languages, as well as within their two languages.

To account for the possibility that the results of the present study were influenced by the linguistic items we chose, word frequency and amount of phonetic overlap were both considered. There was no significant differences in word frequency and amount of phonetic overlap between targets and competitors within or between languages. Similarly, computations on the items in the Spivey & Marian (1999) study did not reveal any significant differences in phonetic overlap between the two languages, or in word frequency between target and competitor items. These results suggest that, while amount of phonetic overlap may play a role in item activation, it is unlikely to have been driving the phenomena reported here. Nevertheless, discarding the two variables as irrelevant to bilingual language processing would be a mistake. A careful study in which word frequency and phonetic overlap were independent variables may prove insightful. For example, if competition occurs from more than one item within the same language, word frequency and amount of phonetic overlap are likely to be important determinants of strength of competition from each item[2].

To conclude, the results of our study provide strong support for parallel spoken language processing in

[2] In comparing the present findings with those of Spivey and Marian (1999), we also observed differences in the latencies of eye movements to the target object depending upon the argument structure of the verb in the spoken instructions. Subjects' saccade latencies were shorter for single-argument verbs such as "Pick up" (as in "Pick up the marker. Put it below the cross.") than for double-argument verbs such as "Put" (as in "Put the marker below the cross"). Interestingly, this pattern of findings was also observed with English monolinguals by Spivey & Tanenhaus (submitted).

bilinguals. Together with other findings of parallel processing in bilinguals, these results suggest that bilingual listeners simultaneously accumulate phonemic input into both of their lexicons (with it presumably cascading to higher levels of representation) as a spoken word unfolds in real time, even when in a monolingual situation. Future efforts in investigating bilingual spoken language processing will need to focus on more systematic manipulation of the language mode, as well as on investigating activation of translated item names and their phonetic neighbors. Moreover, explicit tests of competing theories will eventually require computational models of bilingual language processing (e.g., van Heuven, Dijkstra, & Grainger, 1998) with architectures that can accommodate this apparent interaction between the two languages all the way up and down the processing stream.

Acknowledgements

The authors wish to thank Eugene Shildkrot, Marina Basina, and Olga Kats for their help in constructing stimuli, data collection, and coding, and Tobey Doeleman for help with the phonetic count. This work was supported by a Cognitive Studies Dissertation Fellowship (VM) and a Sloan Foundation Research Fellowship in Neuroscience (MS).

References

Allopenna, P., Magnuson, J., & Tanenhaus, M. (1998). Tracking the time course of spoken word recognition using eye movements: Evidence for continuous mapping models. *Journal of Memory and Language, 38,* 419-439.

Bijeljac-Babic, R., Biardeau, A., & Grainger, J. (1997). Masked orthographic priming in bilingual word recognition. *Memory and Cognition, 25,* 447-457.

Chen, H. C., & Ho, C. (1986). Development of Stroop interference in Chinese-English bilinguals. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 12,* 397-401.

DeGroot, A. & Nas, G. (1991). Lexical representation of cognates and noncognates in compound bilinguals. *Journal of Memory and Language, 30,* 90-123.

Dijkstra, A., Timmermans, M., & Schriefers, H. (1997). Cross-language effects on bilingual homograph recognition. Manuscript in preparation.

Dijkstra, A., van Jaarsveld, H., & ten Brinke, S. (1998). Interlingual homograph recognition: Effects of task demands and language intermixing. *Bilingualism, 1* (1).

Doctor, E. A., & Klein, D. (1992). Phonological processing in bilingual word recognition. In R. J. Harris (Ed.), *Cognitive Processing in Bilinguals.* Amsterdam: Elsevier, pp. 237-252.

Gerard, L. D., & Scarborough, D. L. (1989). Language-specific lexical access of homographs by bilinguals. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 15* (2), 305-313.

Grainger, J. (1993). Visual word recognition in bilinguals. In R. Schreuder & B. Weltens (Eds.), *The Bilingual Lexicon.* Amsterdam: John Benjamins.

Grainger, J., & Dijkstra, A. (1992). On the representation and use of language information in bilinguals. In R. J. Harris (Ed.), *Cognitive Processing in Bilinguals.* Amsterdam: Elsevier.

Grosjean, F. (in press). Studying bilinguals: Methodological and conceptual issues. *Bilingualism: Language and Cognition.*

Grosjean, F. (1999). The bilingual's language modes. In J. L. Nicol and T. D. Langendoen (Eds.). *Language Processing in the Bilingual.* Oxford: Blackwell, 1999.

Kroll, J., & Stewart, E. (1994). Category interference in translation and picture naming: Evidence for asymmetric connections between bilingual memory representations. *Journal of Memory and Language, 33,* 149-174.

Lenngren, L. (Ed.). (1993). *Chastotnyi Slovari Sovremennogo Russkogo Yazyka (Frequency Dictionary of Modern Russian Language).* Uppsala.

Li, P. (1996). Spoken word recognition of code-switched words by Chinese-English bilinguals. *Journal of Memory and Language, 35,* 757-774.

MacNamara, J., & Kushnir, S. (1971). Linguistic independence of bilinguals: The input switch. *Journal of Verbal Learning and Verbal Behavior, 10,* 480-487.

Nas, G. (1983). Visual word recognition in bilinguals: Evidence for a cooperation between visual and sound based codes during access to a common lexical store. *Journal of Verbal Learning and Verbal Behavior, 22,* 526-534.

Preston, M., & Lambert, W. (1969). Interlingual interference in a bilingual version of the Stroop Color-Word Task, *Journal of Verbal Learning and Verbal Behavior, 8,* 295-301.

Soares, C., & Grosjean, F. (1984). Bilinguals in a monolingual and a bilingual speech mode: The effect on lexical access. *Memory and Cognition, 12 (4),* 380-386.

Spivey, M., & Marian, V. (1999). Crosstalk between native and second languages: Partial activation of an irrelevant lexicon. *Psychological Science, 10,* 281-284.

Spivey, M., & Tanenhaus, M. (submitted). Integration of visual context and linguistic information in resolving temporary ambiguities in spoken language comprehension.

Tanenhaus, M., Spivey-Knowlton, M., Eberhard, K., & Sedivy, J. (1995). Integration of visual and linguistic information during spoken language comprehension. *Science, 268,* 1632-1634.

van Heuven, W. J. B., Dijkstra, T., & Grainger, J. (1998). Orthographic neighborhood effects in bilingual word recognition. *Journal of Memory and Language, 39,* 458-483.

Zasorina, L. N. (Ed.) (1977). *Chastotnyi Slovari Russkogo Yazyka (Frequency Dictionary of Russian Language).* Moscow: Russkii Yazyk.

Zeno, S., Ivens, S., Millard, R., Duvvuri, R. (1995). *The Educator's Word Frequency Guide.* Touchstone Applied Science Associates.