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Bilingual and monolingual processing of competing lexical items

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ABSTRACT
Performance of bilingual Russian–English speakers and monolingual English speakers during auditory processing of competing lexical items was examined using eye tracking. Results revealed that both bilinguals and monolinguals experienced competition from English lexical items overlapping phonetically with an English target item (e.g., *spear* and *speaker*). However, only bilingual speakers experienced competition from Russian competitor items overlapping crosslinguistically with an English target (e.g., *spear* and *spichki,* Russian for *matches*). English monolinguals treated the Russian competitors as they did any other filler items. This difference in performance between bilinguals and monolinguals tested with exactly the same sets of stimuli suggests that eye movements to a crosslinguistic competitor are due to activation of the other language and to between-language competition rather than being an artifact of stimulus selection or experimental design.

With the majority of the world's population speaking more than one language (Romaine, 1995), studying bilingualism and multilingualism 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 & Scarborough, 1989; MacNamara & 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), code switching (Grainger, 1993; Grainger & Dijkstra, 1992; Li, 1996; Soares & Grosjean, 1984), interlingual homographs (Dijkstra, Timmermans, & Schriefers, 1997; Dijkstra, van Jaarsveld, & ten Brinke, 1998), cog-

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nates (DeGroot & Nas, 1991; Kroll & Stewart, 1994), and phoneme monitoring (Colome, 2001). Recent evidence for parallel activation comes from visual word recognition tasks that test masked orthographic priming (Bijeljac–Babic, Biardeau, & Grainger, 1997), interlingual neighbors (van Heuven, Dijkstra, & Grainger, 1998), and phonological overlap (Brysbaert, Van Dyck, & Van de Poel, 1999; DeGroot, Delmaar, & Lupker, 2000; Dijkstra, Grainger, & van Heuven, 1999). Attempts to extend the hypothesis of generalized lexical access from the orthographic to the phonological domain using code-switching were also encouraging (Doctor & Klein, 1992; Nas, 1983).

In the auditory domain, some of 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 (Marian, 2000; 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 nonlinguistically. It allows testing the processing of both languages without compromising a monolingual language set, something that is otherwise not possible with spoken language. In the eye-tracking methodology, participants are given spoken instructions to move objects around and their eye movements to the various objects are recorded. Although they rarely pick up incorrect objects, it is often observed that participants briefly fixate objects that have similar phonology to the spoken word. In fact, Allopenna, Magnuson, and Tanenhaus (1998) showed that the probabilities of eye movements to objects with phonological similarity closely match the activation curves of the TRACE model of speech perception (Elman & McClelland, 1986; McClelland & Elman, 1986), thus providing the linking hypothesis between eye movements and lexical activation.

Using this methodology, Spivey and Marian (1999) presented Russian–English bilinguals 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 word *marker*, thus suggesting that lexical items in both languages were activated simultaneously, even though only one language was being used.

Although this work shows crosslinguistic 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 complex visual content. In everyday environments, while processing spoken language, bilinguals are surrounded by a multitude of objects. Some of them do indeed compete crosslinguistically, others compete within the same language, and in many cases there may be simultaneous competition 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 significant competition from the second language into the first language, but not from the first language into the second. We hypothesized that the asymmetry may have been a result of the increased activation of English among the tested bilinguals due to their immersion in an English-speaking environment, as well as possible differences across languages in the stimuli selected on variables such as phonetic overlap and word frequencies. In the present work, we aimed to further study the between-language competition phenomenon observed by Spivey and Marian (1999) while trying to increase the activation of the Russian language and control for amount of phonetic overlap and word frequencies in the two languages. We predicted that between-language competition would be observed from both languages and into both languages.

In addition, 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 et al., 1998; Tanenhaus, Spivey–Knowlton, Eberhard, & Sedivy, 1995), thus extending the within-language competition phenomenon to the bilingual domain. Therefore, we had three goals in studying bilinguals in the present work: (a) to replicate between-language competition from the second language into the first language and examine whether competition from the first into the second language could take place, (b) to examine within-language competition in bilinguals, and (c) to examine language processing during simultaneous competition from both languages.

In addition to bilinguals, a second experiment with monolingual English speakers was run. For this experiment, the same stimuli, setup, procedure and design were used as with bilinguals, but testing was done in English only. The goals of the monolingual experiment were to examine whether, during English trials, monolingual English speakers would experience between-language competition from Russian competitors, within-language competition from English competitors, and/or simultaneous competition from both languages. Performance of the monolingual speakers could then be directly compared to that of the bilingual group on the English part of the experiment. If both bilinguals and monolinguals show competition from English but only bilinguals also show competition from Russian, then it can be concluded that eye movements to phonetically overlapping items are indeed a result of parallel activation of both languages and of between-language competition, rather than an artifact of stimulus selection or study design. If, on the other hand, both groups perform equally in all conditions (showing competition either from both Russian and English or from neither), then the eye-tracking paradigm is ill suited for studying language activation and processing in bilinguals. Testing these hypotheses was the major objective of the monolingual–bilingual comparison.

EXPERIMENT 1

In Experiment 1, Russian–English bilingual speakers were tested in their first and second languages to examine spoken language processing under three conditions: (a) when lexical items competed for activation with a target item between-languages, (b) when lexical items competed for activation with a target item within-language, and (c) when lexical items competed for activation with a target item simultaneously from both between and within languages.

Methods

Participants. Fifteen Russian–English bilinguals participated in the study (5 males, 10 females). All were students at Cornell University, and their mean age was 22.04 years (*SD* = 3.77). All were Russian–English bilinguals who were born in the former Soviet Union and immigrated to the United States at a mean age of 15.62 years (*SD* = 3.65). All participants were fluent in both languages and had obtained sufficiently high scores on standardized SAT tests to be admitted to Cornell; none were enrolled in English as a Second Language classes. When asked what language they used most, participants reported that Russian was the language they used most until the average age of 18 years (i.e., for another 2–2.5 years after immigration), at which point English became the language they used most and remained so for the past 4 years on average. In addition, participants were asked to self-report their language preference. Six participants indicated that Russian was their preferred language, five indicated that English was their preferred language, and four reported no language preference. It is also worth mentioning that this group of bilinguals was similar to that tested by Spivey and Marian (1999). In that study, participants were 7 male and 5 female Russian–English bilinguals with a mean age of 20.35 years at the time of the experiment and 14.01 years at the time of immigration.

All participants were paid for their participation. At the end of the experiment, participants were asked whether they noticed anything unusual and what they thought the objectives of the study were. Normally, in this task any participant who mentions noticing similar sounding object names is excluded from data analyses. In this experiment, none of the participants reported noticing any similarities.

Apparatus. A headband-mounted ISCAN eyetracker was used to record participants' eye movements during the experiment. A scene camera, yoked with the view of the tracked eye, provided an image of the participant's field of view. A second camera, which provided an infrared image of the left eye, allowed the software to track the center of the pupil and the corneal reflection. 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 prerecorded by a fluent Russian–English bilingual speaker who acquired both languages in early childhood and had no noticeable accent in either language. The speech files were recorded and played on a Macintosh computer, and the audio record was synchronized with the video record for data analysis.

Design. 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, which were 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 names 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 had phonetic overlap with the name of the target object. For example, during the English part, if *speaker* was the target object, then *spichki* (*matches*) was the between-language competitor object. 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 phonetic 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 *spichki*, then the within-language competitor was *spitsy* (*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 competition takes place. The four conditions were intermixed throughout the experiment.

For a given target item, across all four of its conditions (between-language competitor present/absent by within-language competitor present/absent), the various competitor and filler objects had fixed locations in which they would be presented. This allowed us to compare eye movements to competitors and fillers by examining fixations of the same location within a display.

Stimuli. A complete list of all target items, between-language competitors, within-language competitors, and fillers for both Russian and English can be found in the appendices.

To avoid potential confounds, in each trial we considered such variables as the physical similarity of the items, the word frequencies in the two languages, and the amount of phonetic 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 balloon 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 and are not considered in the results and discussion.

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 (1993) frequency dictionary based on a corpus of 1,000,000 word tokens, as well as Zasorina's (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. Appendices A and B provide the word frequencies of target, competitor, and filler stimulus items that were used and their translation equivalents.

Phonetic overlap was analyzed based on the raw number of overlapping phonemes and the proportion of word overlap across two items. We performed *T* tests across the two languages and for each language separately. Overlap within and between languages was considered. No significant difference was found in any of the analyses. Tables 1 and 2 provide phonetic transcriptions of stimuli used in the two experiments and amount of phonetic overlap between target and competitor items, following International Phonetic Alphabet transcriptions.

Procedure. Upon arrival to the lab, subjects were greeted and interacted with exclusively in the language appropriate for that part of the experiment. In addition, efforts were made to increase the activation of Russian, because Russian was a passive language in the subjects' overall environment at the time. These efforts included providing all the instructions in Russian prior to the Russian part of the experiment, having subjects sign a Russian-language consent form before the Russian part, and playing popular Russian songs via a tape-recorder at the time of arrival to the lab or before the beginning of the Russian part.

Participants were then seated at arm's length from a 61 by 61 cm white board set on a table. The board was divided into nine 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 different displays of object combinations (20 displays in each language). For each display the subjects were asked to look at the central cross, followed by instructions to manipulate the objects in the display. Examples of verbatim instructions are "Pick up the speaker. Put the speaker below the cross" in English and "Podnimite spichki. Polojite spichki nije krestika" ("Pick up the matches. Put the matches below the cross") in Russian.

For each instruction to manipulate an object from a phonetically overlapping set, there were two filler instructions to manipulate a filler object that did not overlap phonetically with any other item in the display. These filler trials served two purposes. First, they were used to prevent subjects from noticing the overlap and guessing the hypothesis of the study. Second, because the overlapping competitor objects and their corresponding distractor objects all served as filler objects in these filler instructions, we were able to perform control comparisons

Table 1. *Phonetic transcriptions of stimuli used with the English target and amount of phonetic overlap between target and competitor items following International Phonetic Alphabet transcriptions*

	Russian Competitor		English Competitor	
English Target	Item	No. of Overlapping Phonemes at Onset	Item	No. of Overlapping Phonemes at Onset
1. Speaker [spikɚ]	Спички [spit͡ʃki]	3	Spear [spiɹ]	3
2. Boot [but]	Бубен [bubʲɛn]	2	Book [bʊk]	1
3. Shark [ʃɑɹk]	Шарик [ʃɑrik]	2	Shovel [ʃʌvl̩]	1
4. Chair [tʃeɹ]	Черепаха [t͡ʃʲɛrʲɛpɑhə]	1[a,b]	Chess set [tʃɛs sɛt]	1[b]
5. Marker [mɑɹkɚ]	Марка [mɑrkə]	2	Marbles [mɑɹbəlz]	3
6. Barbed wire [bɑɹbd waiɹ]	Бархат [bɑ rhət]	2	Bark [bɑɹk]	3
7. Plug [plʌg]	Платье [plɑtjɛ]	2[a]	Plum [plʌm]	3
8. Gun [gʌn]	Гайка [gɑjkə]	1[a]	Gum [gʌm]	2
9. Card [kɑɹd]	Картошка [kɑrtoʃkə]	2	Car [kɑɹ]	3
10. Lock [lʌk]	Лак для ногтей [lɑk dlʲa nɑgtei]	1[a]	Lobster [lʌbstɚ]	2
Mean		1.80 2.20[c]		2.20
Standard deviation		0.63 0.42[c]		0.92

[a]Indicates strong similarities in vowel quality following the overlap.
[b]Indicates affricate overlap.
[c]The means and standard deviations include the vowels that have strong similarities across languages and are likely to sound the same to a late bilingual.

Table 2. *Phonetic transcriptions of stimuli used with the Russian target and amount of phonetic overlap between target and competitor items, following International Phonetic Alphabet transcriptions*

	English Competitor		Russian Competitor	
Russian Target	Item	No. of Overlapping Phonemes at Onset	Item	No. of Overlapping Phonemes at Onset
1. Спички [spit͡ʃki]	Spear [spiɹ]	3	СпицьI [spitsɨ]	3
2. Бусы [busɨ]	Book [bʊk]	1[a]	Бубен [bubʲɛn]	2
3. Шарик [ʃɑrik]	Shark [ʃɑɹk]	2	Шапка [ʃɑpkə]	2
4. Черепаха [t͡ʃʲɛrʲɛpɑhə]	Chair [tʃeɹ]	1[a,b]	Червяк [t͡ʃɛrvʲak]	3[b]
5. Марка [mɑrkə]	Marker [mɑɹkɚ]	2	Марля [marlʲə]	3
6. Банка [bɑnkə]	Barbed wire [bɑɹbd waiɹ]	2	Бархат [bɑ rhət]	2
7. ПлатЬе [plɑtjɛ]	Plum [plʌm]	2[a]	Плащ [plɑɕ]	3
8. Гайка [gɑjkə]	Gun [gʌn]	1[c]	Галстук [gɑlstək]	2
9. Карта [kɑrtə]	Car [kɑɹ]	2	Картошка [kɑrtoʃkə]	4
10. Лак для ногтей [lɑk dlʲa nɑgtei]	Lock [lʌk]	1[a]	Лопата [lɑpatə]	2
Mean		1.70 2.20[c]		2.60
Standard deviation		0.67 0.42[c]		0.70

[a]Indicates strong similarities in vowel quality following the overlap.
[b]Indicates affricate overlap.
[c]The means and standard deviations include the vowels that have strong similarities across languages and are likely to sound the same to a late bilingual.

and ensure that any observed effects were not a by-product of physical differences between the competitor object and its corresponding filler.

Analyses. Recording of eye movements provided two measures, proportion and pattern. The pattern of eye movements is provided for descriptive purposes only; all inferential statistics were performed on proportions of eye movements. The proportion of eye movements to the competitor item in a competition condition was compared to the proportion of eye movements to a nonoverlapping filler item in the same location in the control condition. This allowed us to tabulate the proportion of trials in which the participants looked at the same display square across conditions, with that square containing either a control filler object or a competitor object. Three-way analyses of variance (ANOVAs) were performed for between-language and within-language competition, using language (Russian vs. English), between-language competition (present vs. absent), and within-language competition (present vs. absent). These analyses were performed across all four conditions: for example, if both the between-language competition variable and the within-language competition variable indicated absent, then that referred to the control condition; if only one indicated present, this referred to competition from one language only; and if both indicated present, then that referred to the simultaneous competition condition. Because the between-language competitor and the within-language competitor were necessarily in different locations in the display (and were present simultaneously in one of the conditions) and because they had different objects as their corresponding control fillers, we conducted separate three-way repeated-measures ANOVAs for eye movements to the between-language competitor location and the within-language competitor location.

Results

Proportion of eye movements. The proportion of eye movements to competitor items was compared to the proportion of eye movements to filler items in the same location. Three-way ANOVAs (language, presence or absence of between-language competitor, and presence or absence of within-language competitor) were computed by subjects and by items for between-language competition (i.e., looks to the display square that contained either the between-language competitor or the control filler object). Results revealed a main effect of presence or absence of the between-language competitor. Russian–English bilinguals looked at the between-language competitor in 15% of all trials and to the control filler in the same location in 6% of all trials. This difference was significant by both subjects and items, $F1\ (1, 14) = 7.40$, $p < .05$; $F2\ (1, 16) = 5.24$, $p < .05$. No effects of language (Russian vs. English) or presence/absence of the within-language competitor were observed, suggesting that bilinguals experienced between-language competition in both languages during between-language competition trials and simultaneous competition trials. There was no interaction between any of the variables.

A similar $2 \times 2 \times 2$ ANOVA was performed for within-language competition.

The results suggested a main effect of presence or absence of the within-language competitor but no effect of language or presence/absence of the between-language competitor. For within-language competition, Russian–English bilinguals looked at the within-language competitor in 20% of all trials and to the control filler in the same location in 10% of all trials. This difference was significant both by subjects and by items, $F1\ (1, 14) = 10.05$, $p < .01$; $F2\ (1, 16) = 8.06$, $p < .05$. No interaction between variables was observed. That is, bilinguals experienced within-language competition in both their first language and their second language during within-language competition trials and simultaneous competition trials.

A comparison of the first and second halves of the experiment in order to test for order effects failed to reveal a significant difference in patterns of competition. Within-language competition, between-language competition, and simultaneous within- and between-language competition were not significantly different in the two parts.

Eye-movement patterns. To get a sense of the time course of fixations, the pattern of bilinguals' eye movements was examined. When only the between-language competitor was present and participants fixated it, they did so on at average of 475 ms after the onset of the target word. On those trials, they then fixated the target object an average of 817 ms after the onset of the target word. When only the within-language competitor was present and participants fixated it, they did so 602 ms after the onset of the target word. On those trials, they looked at the target object an average of 808 ms after the onset of the target word.

In the simultaneous within- and between-language competition condition, of the times when there was a look to a competitor object, 56% of the time the look was to a within-language competitor only, 32% of the time the look was to a between-language competitor only, and 12% of the time participants looked at both within- and between-language competitors. On those few trials when participants looked at both within- and between-language competitors, 50% of the time they looked at the within-language competitor first and 50% of the time they looked at the between-language competitor first. In the simultaneous competition condition, participants looked at the between-language competitor, the within-language competitor, and the target an average of 600, 889, and 860 ms, respectively, after the onset of the target word. An example of the eye movements in a simultaneous between- and within-language competition trial is shown in Figure 1. When instructed to pick up the target object *busi* (*beaded necklace*), the subject made an eye movement to the between-language competitor *book* at 300 ms after the onset of the target word, followed by an eye movement to the within-language competitor *buben* (*tambourine*) at 633 ms after the onset of the target word, before finally looking at the target object 1267 ms after the onset of the target word and picking it up.

Control comparisons. Phonetic mapping from sound to object is not the only factor that drives eye movements. Due to purely visual properties, some objects tend to attract a participant's attention more than others. When selecting our stimuli, we specifically ensured that our phonetically overlapping competitors

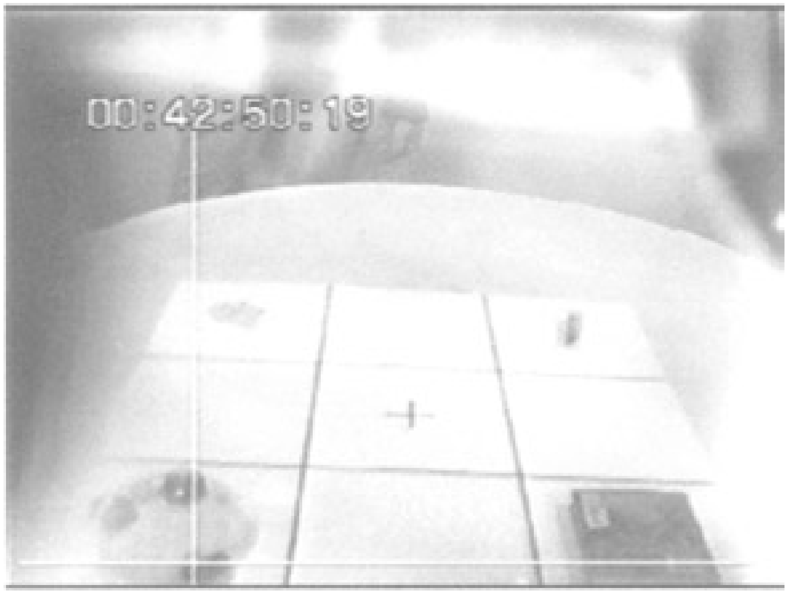

Figure 1. A view from the scene camera showing the simultaneous between- and within-language competition condition. The target object in the upper left corner is *busi* (beaded necklace), the within-language competitor in the lower left corner is *buben* (tambourine), the between-language competitor in the lower right corner is *book* (*kniga*), and the filler object in the upper right corner is *lipstick* (*pomada*). The crosshairs indicate the subject's fixation on the within-language competitor *buben*.

were not more visually attractive than their corresponding fillers. To completely rule out the possibility that our results were driven by such physical properties, control comparisons were performed for between-language, within-language, and simultaneous between- and within-language competition. We compared the proportion of eye movements to competitor objects and their corresponding distractor objects during filler instructions to pick up a target that bore no phonetic similarity to either object name.

When the between-language competitor and its corresponding distractor both served as fillers, participants looked at the between-language competitor 16% of the time and at its corresponding filler 19% of the time ($p > .1$). When the within-language competitor and its corresponding distractor both served as fillers, participants looked at the within-language competitor 19% of the time and at its corresponding filler 27% of the time ($p > .1$). When both the between-language competitor and the within-language competitor served as fillers, participants looked relatively equally at the two competitors and their corresponding fillers. They looked at the between-language competitor 17% of the time and its corresponding filler 19% of the time ($p > .1$), and they looked at the within-language competitor 17% of the time and its corresponding filler 27% of the time ($p < .1$). Analyses by language showed that participants did not look at the corresponding fillers significantly more than at the competitor objects. The relatively higher overall proportion of looks in the control comparisons was due to the fact that, in these instructions, participants did not fixate on the central cross and therefore made more eye movements to objects in the display overall. These results show that, during filler instructions, participants looked relatively equally at the between-language competitors and their corresponding fillers and at the within-language competitors and their corresponding fillers when there was no phonetic overlap with the target. This suggests that physical differences between the overlapping competitor object and its corresponding filler object were not responsible for the observed between- and within-language competition effects.

EXPERIMENT 2

Monolingual English speakers were tested under the same conditions and with exactly the same sets of stimuli (from the English session) to allow direct comparisons between performance of bilingual speakers in Experiment 1 and performance of monolingual speakers in Experiment 2. The monolingual speakers were tested in English only and their eye movements were recorded under four conditions: (a) a control condition in which there was no phonetic overlap among any items in the display, (b) a between-language competition condition in which Russian lexical items competed for activation with an English target, (c) a within-language competition condition in which English lexical items competed for activation with an English target, and (d) a simultaneous competition condition in which both English and Russian lexical items competed for activation with an English target. The hypotheses were that monolingual English speakers will show significant competition from English competitors in both the within-language competition condition and the simultaneous competition condition, but they will show no competition from Russian items in either the between-language competition condition or the simultaneous competition condition.

Methods

Participants. Twelve English monolinguals participated in the study (5 males, 7 females). All were students at Cornell University; their mean age was 19.6 years ($SD = 0.99$). None of them knew Russian or had studied Russian at any time in their lives. Informed consent was obtained and participants' rights were protected. All participants were paid for their participation. At the end of the experiment, participants were asked whether they had noticed anything unusual and what they thought the objectives of the study were. Normally in this task, any participant who mentions noticing similar sounding object names is excluded from data analysis. In this experiment, none of the participants reported noticing any similarities.

Apparatus and stimuli. The same eye-tracking equipment and the same sets of stimuli were used with monolinguals tested in Experiment 2 as with the bilinguals tested in Experiment 1. Because the English set that included *card* as a target was dropped from the bilingual analyses, this set was not used with the monolinguals.

Design and procedure. The design of Experiment 2 followed that of Experiment 1 except that all trials were presented in English only. All participants were tested with 36 English trials, of which 9 were control trials, 9 were between-language competition trials, 9 were within-language competition trials, and 9 were simultaneous between- and within-language competition trials.

Analyses. The proportion of eye movements to competitor items was compared to the proportion of eye movements to a noncompeting filler item in the same position. As in the bilingual experiment, the between-language competitor and the within-language competitor were necessarily in different locations in the display (and were present simultaneously in one of the conditions) and had different objects as their corresponding control fillers. Therefore, we conducted separate repeated-measures ANOVAs for eye movements to the between-language competitor location and for eye movements to the within-language competitor location. These analyses were performed across all four conditions: the independent variables were presence or absence of the between-language competitor and presence or absence of the within-language competitor, and the dependent variable was proportion of eye movements made to the relevant location in the display.

Results

Analyses of variance were performed by subjects and by items on proportion of looks to competitor items and to control fillers across all four conditions. Monolingual English speakers looked at the within-language English competitor in 20% of all trials and to nonoverlapping control fillers on 8% of all trials. This difference was significant both by subjects and by items, $F1\ (1, 11) = 12.21$, $p < .01$; $F2\ (1, 8) = 10.45$, $p < .05$. There was no effect of presence or absence of the between-language competitor and no interaction among variables, indicating that monolinguals made eye movements to the English competitor in the within-language competition condition as well as in the simultaneous competition condition.

Similar analyses of variance for looks to the Russian competitor revealed no significant effects. Monolingual English speakers looked at the between-language Russian competitor in 5% of all trials and to the nonoverlapping control filler in 8% of all trials, $F1\ (1, 11) = 3.08$, $p > .1$; $F2\ (1, 8) = 1.22$, $p > .1$, with no interaction between variables. These results suggest that English monolinguals treated the Russian competitor as they would any other nonoverlapping control filler.

DISCUSSION

Additional analyses were performed across both experiments, treating linguistic status (monolinguals vs. bilinguals) as a between-subject variable to compare performance of both bilinguals and monolinguals on the English part of the experiment. A 2 × 2 × 2 ANOVA (language, presence/absence of the between-language competitor, and presence/absence of the within-language competitor) revealed a main effect of within-language competitor presence. Across both experiments, participants looked at the English competitor in 20% of all trials and at the nonoverlapping control filler in 8% of all trials. This difference was significant both by subjects and by items, $F1$ (1, 25) = 15.575, $p < .01$; $F2$ (1, 8) = 20.38, $p < .01$. No interaction between variables was observed. These findings suggest that both bilinguals and monolinguals experienced competition from items overlapping with the target item in English.

For competition from Russian, across both experiments, participants looked at the Russian competitor in 11% of all trials and at the nonoverlapping control filler in 7% of all trials, $F1$ (1, 25) = 7.148, $p < .05$; $F2$ (1, 8) = 1.90, $p > .1$. A significant interaction with linguistic status (monolingual vs. bilingual) was observed, $F1$ (1, 25) = 14.57, $p < .01$; $F2$ (1, 8) = 5.831, $p < .05$. This suggests that the difference in the proportion of eye movements to the Russian competitor and the control filler was an artifact of the interaction and was due to performance of bilingual participants only. Namely, during the English session, bilingual Russian–English speakers looked at the Russian competitor objects in 17% of all trials and at the nonoverlapping control filler in the same location on 6% of all trials, whereas monolingual English speakers looked at the Russian competitor objects in 4% of all trials and at the nonoverlapping control filler in the same location on 7% of all trials. This pattern of eye movements suggests that Russian–English bilinguals made eye movements to the Russian competitor to the same extent as they did to the English competitor. However, English monolingual speakers, not knowing Russian, treated the Russian competitor as any other filler in the display and did not make more eye movements to items overlapping phonetically in Russian.

The present study reinforces the hypothesis of parallel activation of two languages during bilingual language processing. The main effect of between-language competition across languages replicates the basic finding of Spivey and Marian (1999). However, they found that competition was stronger from the second language into the first, while in the present study significant between-language competition was observed from both languages and into both languages. These differences in results suggest that factors such as stimulus selection and the overall degree of activation of a language influence the extent to which languages compete during processing. Ensuring equal phonetic overlap between competitor and target items in both languages, controlling for word frequencies, and boosting activation of the language not used in daily environments resulted in a study that was cleaner and better balanced across languages. These differences suggest that subtle experimental manipulations may alter a bilingual's performance and influence the pattern of language processing. The finding that the activation of a language and the degree to which it shows interference may be malleable by experimental manipulation is in itself an interesting idea, one that further calls attention to methodological designs of bilingual experiments. Moreover, in the future, a careful study in which word frequency and phonetic overlap are independent variables may prove insightful. For example, if competition is tested for 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.

Our study was the first to consider eye-tracking 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. An investigation of simultaneous within- and between-language competition during bilingual spoken language processing suggests that competition in bilinguals takes place from both the first and second languages at the same time. The results of the bilingual experiment 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.

This conclusion is further strengthened by the pattern of performance observed in the monolingual English speakers tested in Experiment 2 and by the direct comparison between monolingual performance and bilingual performance on the English part of Experiment 1. The fact that monolinguals experience within-language competition is not a new finding in itself (Tanenhaus et al., 1995). What is interesting about Experiment 2 is that the English monolinguals showed within-language competition that was very similar to the bilinguals tested in Experiment 1, but they showed a drastic difference for between-language competition. These similarities in performance for within-language competition and differences in performance for between-language competition are interpreted as supporting parallel activation at the phonological level of the two languages in bilinguals. They suggest that the between-language competition effect is genuine and not an artifact of biased stimulus selection or design.

To conclude, the results of our study provide strong support for parallel spoken language processing in bilinguals. We observed robust between-language and within-language competition effects in both languages. Together with other findings of parallel processing in bilinguals, these results suggest that bilingual listeners simultaneously accumulate phonemic input into both of their lexicons (which presumably cascades to higher levels of representation) as a spoken word unfolds in real time, even when in a monolingual situation. In fact, given the accumulating evidence for cross-linguistic competition (Bijeljac–Babic et al., 1997; Spivey & Marian, 1999; van Heuven et al., 1998), the assumption of two separate lexical modules for word recognition may be challenged. Moreover, explicit tests of competing theories will eventually require computational models of bilingual language processing (e.g., Dijkstra, van Heuven, & Grainger, 1998) with architectures that can accommodate this apparent interaction between the two languages throughout the entire processing stream.

APPENDIX A

WORD FREQUENCIES FOR TARGET, COMPETITOR, AND FILLER ITEMS USED IN THE ENGLISH PART AND FOR THEIR TRANSLATION EQUIVALENTS IN RUSSIAN

Word frequencies in the English language

English Target		Between-Language Competitor				Within-Language Competitor				Noncompeting Filler	
Target	Word Frequency	Engl. Transl. of Russ. Competitor	Word Frequency	Filler	Word Frequency	English	Word Frequency	Filler	Word Frequency	Filler	Word Frequency
1. Speaker	42.373	Matches	12.041	Disk	18.00289	Spear	12.098	Plate	65.41	Toothbrush	3.59
2. Boot	8.336	Tambourine	0.0521	Mitten	2.60492	Book	301.418	Hair clip	216.61/5.96	Lipstick	1.74
3. Shark	16.44	Balloon	39.884	Pear	2.83647	Shovel	9.899	Train	96.73	Microphone	6.9465
4. Chair	95.224	Turtle	24.66	Fork	15.86	Chess set	5.847	Ruler	35.5847	Lightbulb	0.06
5. Marker	3.878	Stamp	20.724	Dental floss	24.14	Marbles	7.294	Perfume	6.95/51.06	Key chain	86.14/54.13
6. Barbed wire	0.81	Velvet	14.645	Pin	17.25036	Bark	41.158	Sponge	11.29	Screwdriver	3.1838
7. Plug	9.088	Dress	63.213	Knife	40.17	Plum	4.978	Razor	3.76	Moose	11.2301
8. Gun	51.809	Nut	9.841	Fish	260.03	Gum	14.819	Tea bag	54.5/77.68	Spoon	13.1404
9. Card	73.169	Potato	17.482	Napkin	4.63	Car	270.97	Lizard	9.6093	Shoelace	1.447
10. Lock	21.592	Nail polish	19.913/17.771	Watch	15.8032	Lobster	5.036	Eye	132.735	Pencil	35.95
Mean	32.272		21.84		40.13		67.35		59.07		19.78
Standard deviation	30.644		16.89		78.08		116.05		61.92		27.78

Word frequencies in the Russian language

English Target			Between-Language Competitor						Within-Language Competitor						Noncompeting Filler		
	Word Frequency			Word Frequency			Word Frequency			Word Frequency			Word Frequency			Word Frequency	
Russ. Trans. of Engl. Target	1993	1977	Russian	1993	1977	Filler	1993	1977	Russ. Trans. of Engl. Competitor	1993	1977	Filler	1993	1977	Filler	1993	1977
1. колонка	10	4	спички	32	83	дискета	NA	NA	копье	21	9	тарелка	31	48	Зубная щетка	NA	5/41
2. сапог	106	123	бубен	NA	3	варежка	NA	12	книга	231	691	заколка	NA	NA	помада	NA	7
3. акула	NA	4	шарик	31	24	груша	NA	31	лопата	17	33	поезд	67	128	микрофон	NA	13
4. стул	65	98	черепаха	NA	1	вилка	NA	7	шахматы	22	8	линейка	NA	10	лампочка	23	30
5. фломастер	NA	NA	марка	19	28	зубная нитка	NA/34	5/32	шарики	NA	NA	духи	NA	6	брелок	NA	NA
6. колючая проволока	19/19	10/27	бархат	NA	15	булавка	NA	12	кора	53	43	мочалка	NA	3	отвертка	NA	2
7. слива	NA	7	платье	74	71	нож	72	NA	слива	NA	11	бритва	NA	7	лось	NA	5
8. пистолет	22	28	гайка	23	7	рыбка	NA	16	жевательная резинка	NA	NA	чайный мешочек	NA/10	224	ложка	34	41
9. открытка	25	18	картошка	68	28	салфетка	NA	16	машина/ка	465/12	523/11	ящерица	NA	4	шнурок	NA	6
10. замок	21	31	лак для ногтей	10/3304/20	3/3254/18	часы	61	150	рак	20	22	глаз	971	1093	карандаш	23	75
Mean	57.5	45		41.7	28.889		71	45.7		105.13	150.11		294.25	169.22		26.67	22.5
Standard deviation	63.12	46.5		23.69	29.26		61.26	64.24		162.89	262.68		452.26	354.61		6.351	23.88

APPENDIX B

WORD FREQUENCIES FOR TARGET, COMPETITOR, AND FILLER STIMULUS ITEMS USED IN THE RUSSIAN PART AND FOR THEIR TRANSLATION EQUIVALENTS IN ENGLISH

Word frequencies in the English language

Russian Target		Between-Language Competitor				Within-Language Competitor				Noncompeting Filler	
Engl. Trans. of Russ. Target	Word Frequency	English	Word Frequency	Filler	Word Frequency	Engl. Trans. of Russ. Competitor	Word Frequency	Filler	Word Frequency	Filler	Word Frequency
1. Matches	12.041	Spear	12.098	Disk	18.00289	Knitting needles	0.058	Plate	65.41	Toothbrush	3.59
2. Necklace	4.863	Book	301.418	Mitten	2.60492	Tambourine	0.521	Hair clip	216.61/5.96	Lipstick	1.74
3. Ballon	39.884	Shark	16.44	Pear	2.83647	Hat	80.289	Train	96.73	Microphone	6.9465
4. Turtle	24.66	Chair	95.224	Fork	15.86	Worm	16.266	Ruler	35.5848	Lightbulb	0.06
5. Stamp	20.724	Marker	3.878	Dental floss	24.14	Cheesecloth	1.216	Perfume	6.95/51.06	Keychain	86.14/54.13
6. Jar	39.421	Barbed wire	0.81	Pin	17.25036	Velvet	14.645	Sponge	11.29	Screwdriver	3.1838
7. Dress	63.213	Plum	4.978	Knife	4017	Raincoat	3.763	Razor	3.76	Moose	11.2301
8. Nut	9.841	Gun	51.809	Fish	260.03	Tie	30.333	Tea bag	54.50/77.68	Spoon	13.1404
9. Map	183.329	Car	270.97	Napkin	4.63	Potato	17.482	Lizard	9.6093	Shoelace	1.447
10. Nail polish	19.913/17.771	Lock	21.592	Watch	15.8032	Shovel	9.899	Eye	132.735	Pencil	35.95
Mean	39.61		77.92		40.13		17.45		59.07		19.78
Standard deviation	50.51		113.64		78.08		24.09		61.92		27.78

Word frequencies in the Russian language

Russian Target			Between-Language Competitor						Within-Language Competitor						Noncompeting Filler		
	Word Frequency			Word Frequency			Word Frequency			Word Frequency			Word Frequency			Word Frequency	
Target	1993	1977	Russ. Trans. of Engl. Competitor	1993	1977	Filler	1993	1977	Russian	1993	1977	Filler	1993	1977	Filler	1993	1977
1. спички	32	83	копье	21	9	дискета	NA	181	спицы	NA	2	тарелка	31	48	зубная щетка	NA	5/41
2. бусы	NA	6	сапог	231	691	варежка	NA	7	бубен	NA	3	заколка	NA	NA	помада	NA	7
3. шарик	31	24	акула	NA	4	груша	NA	31	шапка	62	77	поезд	67	128	микрофон	NA	13
4. черепаха	NA	1	стул	65	98	вилка	NA	7	червяк	13	5	линейка	NA	10	лампочка	23	30
5. марка	19	28	фломастер	NA	NA	зубная нитка	34	5/32	марля	NA	2	духи	NA	6	брелок	NA	NA
6. банка	47	62	колючая проволока	19/9	10/27	булавка	NA	12	бархат	NA	15	мочалка	NA	3	отвертка	NA	2
7. платье	74	71	слива	NA	11	нож	72	NA	плащ	34	13	бритва	NA	7	лось	NA	5
8. гайка	23	7	пистолет	22	28	рыбка	NA	16	галстук	18	21	чайный мешочек	108	224	ложка	34	41
9. карта	83	154	машина/ка	465/12	523/11	салфетка	NA	16	картошка	68	28	ящерица	NA	4	шнурок	NA	6
10. лак для ногтей	10/3304/20	3/3254/18	замок	21	31	часы	61	150	лопата	17	33	глаз	971	1093	карандаш	23	75
Mean	44.14	48.44		97.22	131.18		71	45.7		35.33	19.9		294.25	169.22		26.67	22.5
Standard deviation	25.20	49.77		154.50	239.63		61.26	64.24		24.15	22.90		452.26	354.61		6.35	23.88

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