Research Report

CROSS TALK BETWEEN NATIVE AND SECOND LANGUAGES: Partial Activation of an Irrelevant Lexicon

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Abstract—*Bilingualism provides a unique opportunity for exploring hypotheses about how the human brain encodes language. For example, the "input switch" theory states that bilinguals can deactivate one language module while using the other. A new measure of spoken language comprehension, headband-mounted eyetracking, allows a firm test of this theory. When given spoken instructions to pick up an object, in a monolingual session, late bilinguals looked briefly at a distractor object whose name in the irrelevant language was initially phonetically similar to the spoken word more often than they looked at a control distractor object. This result indicates some overlap between the two languages in bilinguals, and provides support for parallel, interactive accounts of spoken word recognition in general.*

Understanding how the human brain can represent two different languages at once is important not only for understanding bilingualism, but also for understanding the human language capacity in general (de Groot & Kroll, 1997; Schreuder & Weltens, 1993). The traditional account of bilingual language processing posits that the brain has an "input switch" that can activate one language and deactivate the other (e.g., Macnamara & Kushnir, 1971). The input-switch account is an intuitively attractive one, in that it provides a simple explanation for how a bilingual can map the input of one language onto the appropriate mental lexicon and apparently ignore the occasional spurious mappings of that input onto the irrelevant mental lexicon. Moreover, this account is supported by psycholinguistic experiments demonstrating that a written word presented in one language (e.g., *perro,* in Spanish) tends not to produce long-term partial activation, or transfer, for words from the other language that have the same meaning (e.g., *dog,* in English; Gerard & Scarborough, 1989; Kirsner, Brown, Abrol, Chadha, & Sharma, 1980; Scarborough, Gerard, & Cortese, 1984; Watkins & Peynircioglu, 1983). A recent neurophysiological finding that corroborates this modular kind of account comes from functional magnetic resonance imaging of Broca's area in late bilinguals, which depicts the activation of two separate, nonoverlapping regions during subvocal production of the two different languages (Kim, Relkin, Lee, & Hirsch, 1997).

In contrast to the evidence for two separate modules of lexical representation in bilingual brains, results from some recent research indicate significant overlap between the orthographic representations of a bilingual's two languages. For example, when a written prime word from one language is flashed on a computer screen for 57 ms, and a word from the other language is presented as a lexical decision target, reaction times are slower if the orthographies of the target and prime are similar than if they are not (Bijeljac-Babic, Biardeau, & Grainger, 1997). This cross-linguistic inhibitory orthographic priming suggests that (at least when the two languages use similar alphabets) there is a common set of orthographic representations that activate lexical representations from both languages simultaneously and automatically (Grainger, 1993).

In the auditory domain, however, results have been less clear. Although certain studies have indicated a facile interaction between the two languages during spoken word recognition, these studies have involved code-switching situations (i.e., the subject is listening to speech input mixed from both languages; e.g., Grosjean, 1988; Li, 1996). Code switching is a case in which one would not expect the listener to deactivate one lexicon while using the other, even if he or she could. A specific test of the input-switch account of bilingual spoken language comprehension requires that the speech input be restricted to only one of the bilingual's languages. That is, the test must involve a monolingual experimental session, in which subjects have every reason to deactivate their irrelevant lexicon if they can. Until now, it has been essentially impossible to test the activation of a lexical item in the irrelevant language without somehow presenting a stimulus from that irrelevant language—thus compromising the monolingual session.

In the present study, we tested the input-switch account using spoken language stimuli and monolingual stimulus sets. This was possible because the headband-mounted eyetracking methodology provides an on-line index of spoken language comprehension by recording what objects the listener looks at (Tanenhaus, Spivey-Knowlton, Eberhard, & Sedivy, 1995). For example, previous work has shown that monolingual subjects will briefly look at a distractor object whose name has initial phonological similarity with the spoken word; for example, they will glance first at a candle when instructed to "pick up the candy" (Spivey-Knowlton, Tanenhaus, Eberhard, & Sedivy, 1998).[1] In the present experiment, we were able to deliver spoken stimuli in one language and infer the activation of lexical items in the other language without actually compromising the monolingual speech mode.

METHOD

Subjects

Twelve late Russian-English fluent bilinguals, who were naive to the experimental manipulation, participated in the experiment. Russian was their primary language for the first 16 years of life (on average), and English was their primary language for the last 4 years (on average). Of the 12 subjects, 2 stated that Russian was their preferred language at the time of the study, 5 stated that English was their preferred

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1. Partway through a spoken word (e.g., "ca . . . "), multiple lexical candidates (e.g., can, cat, candle, candy) are partially activated (Marslen-Wilson, 1987), and a listener's eye movements are sensitive to these activation levels. Thus, a listener will often "jump the gun" and look briefly at a distractor object whose name matches the initial acoustic-phonetic input of a word, and then make a second eye movement to the correct object.

language, and 5 stated that they had no preference between Russian and English.

Stimuli

In separate Russian and English sessions, we gave prerecorded instructions to the subjects. For example, one instruction in the Russian session was "Poloji marku nije krestika" ("Put the stamp below the cross"). In the *interlingual-distractor-present* condition, the stamp ("marka") was accompanied by an object whose English name, "marker," shares initial phonetic features with the inflected Russian word, "marku." Also included among the objects the subjects viewed were two filler objects whose English and Russian names bore no phonetic similarity to the target word. (If the English lexicon was not deactivated during monolingual Russian comprehension, then when a subject heard "Poloji mark . . . ," the English lexical representation for "marker" should have been partially activated, and some subjects should have made brief eye movements to the marker.) This condition was compared with an *interlingual-distractor-absent* condition, in which the interlingual distractor object (e.g., the marker, called "flomaster" in Russian) was replaced by a control distractor object (e.g., a ruler, called "lineika" in Russian) whose name bore no phonetic similarity with the inflected spoken word ("marku"). A mirror-image version of the experiment was conducted with English instructions. The following 10 pairs of objects (roughly balanced for frequency) were used as targets and interlingual distractors for each other: submarine–"sobaka" (dog), marker–"marka" (stamp), fish–"fishka" (game piece), speaker–"speachky" (matches), glove–"glaz" (eye), bunny–"bunka" (jar), convertible–"konviert" (envelope), chess piece–"chesi" (watch), lock–"loshka" (spoon), and shark–"sharik" (balloon).

Procedure

Eye movements were monitored with an ISCAN camera that was mounted on an adjustable headband. The camera provided an infrared image of the eye at 60 Hz. The center of the pupil and the corneal reflection were tracked to determine direction of gaze relative to the head. This equipment determines direction of gaze with an accuracy better than 1° of arc and allows virtually unrestricted head and body movements. Prerecorded instructions were played over speakers and routed to a hi-8 video recorder that also recorded the subject's field of view (from a second head-mounted camera), with the subject's eye position superimposed as crosshairs.

Subjects were seated at arm's length from a white board set on a table. The board, which measured 61 cm by 61 cm, was divided into nine equal squares and, from the perspective of the subject, spanned approximately 35° of visual angle horizontally and 30° vertically. A black cross in the center square served as a neutral fixation point, where the subject's gaze was directed at the onset of an instruction set. Each subject was tested in two separate sessions: a monolingual Russian session and a monolingual English session (order was counterbalanced across subjects). So that no instruction was repeated (translated) across the two versions of the experiment, nonoverlapping halves of the stimulus set were used for the two sessions. During each session, all instructions, comments between experimenters, and even the consent form were in the appropriate language for that session. In each of the two sessions, 10 critical instructions (five target objects with their interlingual distractors present, and the same five with their interlingual distractors absent) were embedded among 50 filler instructions.

RESULTS

Analyses of variance were computed by subjects (F_1) and by items (F_2). Across the two versions of the experiment, subjects were indeed more likely to make eye movements to incorrect objects when an interlingual distractor object (such as a marker, when hearing "marku") was present in the display (52% of the time) than when it was replaced by an irrelevant control distractor object (such as a ruler, "lineika" in Russian; 37% of the time), $F_1(1, 11) = 5.01$, $p < .05$; $F_2(1, 9) = 5.79$, $p < .05$. We also conducted a finer-grain analysis of how often subjects looked not just at any incorrect object, but particularly at the interlingual distractor (in the interlingual-distractor-present condition) or the control distractor that had replaced it (in the interlingual-distractor-absent condition). Across the two versions of the experiment, subjects made significantly more eye movements to the interlingual distractor (31%) than to the control distractor (13%), $F_1(1, 11) = 8.56$, $p < .02$; $F_2(1, 9) = 12.05$, $p < .01$. There was no main effect of language ($F_1 < 1$; $F_2 < 1$).

Figure 1 is an image from the eyetracker's video output, showing the subject's field of view with crosshairs superimposed to indicate eye position. The time code in the upper left corner shows the hour, minute, second, and video frame (30 Hz). This frame is from a trial in which the display contained, clockwise from the top left, a marker ("flomaster"), a key chain ("brelock"), a stamp ("marka"), and a quarter ("dvadtsati piati tsentof"). The instruction was "Poloji marku nije krestika" ("Put the stamp below the cross"). This image shows that 200 ms after the beginning of the word "marku" (at approximately "Poloji mar . . . "), the subject looked at the marker. On this trial, 233 ms later, the subject then looked at the stamp, picked it up, and put it in the square below the central cross—unaware that his eyes had been briefly distracted by the marker.

Although the interaction between distractor type and language did not approach significance ($F_1 < 1$; $F_2 < 1$), it appears that the main effect of distractor type may have been due more to the Russian-instruction version than the English-instruction version. In the Russian version, subjects made significantly more eye movements to the interlingual distractor object (32%) than to the control distractor object (7%), $F_1(1, 11) = 15.42$, $p < .01$; $F_2(1, 9) = 9.62$, $p < .02$. In the English version, however, the difference was not significant: 29% to the interlingual distractor, 18% to the control distractor, $F_1(1, 11) = 1.15$, $p > .3$; $F_2(1, 9) = 1.90$, $p > .2$. (See Fig. 2.)

In the monolingual Russian version of the experiment (Fig. 2a), subjects frequently (32% of the time) looked initially at the interlingual distractor (e.g., the marker) an average of 110 ms after the end of the word referring to the object to be moved (e.g., "marku"). A few hundred milliseconds later, they would look at the target object (e.g., the stamp), and carry out the instruction. (This pattern held true for 8 of the 10 stimulus pairs.) By comparison, in the control condition, in which the interlingual distractor object was replaced by an unrelated object, subjects tended to ignore that region of the board, simply looking at the target object to carry out the instruction. In the monolingual English version of the experiment (Fig. 2b), there were approximately as many eye movements to the interlingual distractor as in the Russian version. However, there was a substantial number of eye movements

Fig. 1. View showing a subject's fixation (crosshairs) on an interlingual distractor ("marker," upper left object) upon being instructed, in Russian, to pick up the stamp ("Poloji marku nije krestika"; the stamp is the lower right object).

to the control distractor as well, reflecting a general tendency to scan the entire display before settling on the target object (regardless of the objects' names) when the instructions were in English. This asymmetry in the results across the two languages (English appears to systematically interfere with Russian, but Russian interferes less with English) warrants further study. An analysis in which 3 of the English-biased subjects were removed from the data did not change the results, suggesting that the asymmetry may not be due to the slight preference for English among our 12 subjects. Instead, the asymmetry in these results may be due to the fact that all of these subjects were currently immersed in an English-speaking environment.[2]

DISCUSSION

The results in Russian, in particular, demonstrate that, contrary to the traditional psycholinguistic account of bilingual language processing (e.g., Macnamara & Kushnir, 1971), bilingual listeners do not appear to be able to deactivate the irrelevant mental lexicon when in a monolingual situation. In the context of previous research indicating independence of the two mental lexicons in bilinguals (e.g., Gerard & Scarborough, 1989; Kim et al., 1997; Kirsner et al., 1980; Scarborough et al., 1984; Watkins & Peynircioglu, 1983), there exists at least one model of bilingual cognitive architecture that may accommodate much of the existing data. There could perhaps be two semimodular mental lexicons in bilinguals. However, there would need to be a single common acoustic-phonetic system that provides differential, parallel, and automatic mapping to the two lexicons, perhaps with no language-specific intermediate phonemic representations (cf. Marslen-Wilson & Warren, 1994). With this basic cognitive architecture, there is in fact no need to postulate a switching mechanism that is somehow voluntarily triggered (Paradis, 1980). Spoken language automatically activates both mental lexicons in parallel, but activates one of them only partially because the mapping has only a partial match.

This cognitive model of bilingualism is particularly amenable to treating monolingual speech and code switching as regions of a language-mixing continuum (Grosjean, 1992; Hernandez, Bates, & Avila, 1994), rather than as discrete modes of processing. Future exploration of this general account of bilingual language processing will involve

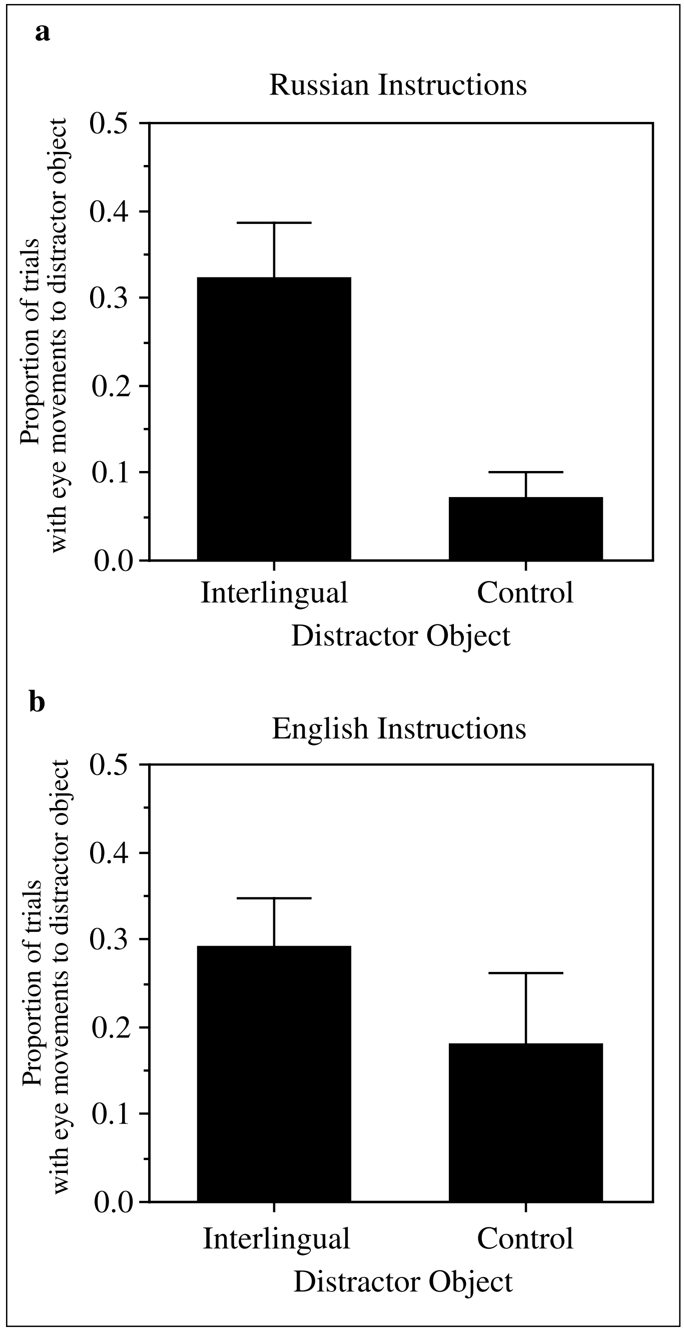

Fig. 2. Mean proportion of trials in which subjects looked at distractor objects in the display. (Error bars encompass one standard error of the mean.) Results are shown separately for the Russian (a) and English (b) versions of the experiment.

2. Preliminary results from a follow-up study replicate the basic result (with data pooled across Russian and English sessions). Moreover, when greater time and effort were put into instilling a Russian environment in the laboratory, the English session showed reliable interference from Russian.

extending this paradigm to more purely monolingual situations (e.g., Grosjean, 1998), as well as to early bilinguals, for whom the two languages might be more equally represented.

In general, our findings are consistent with parallel, interactive accounts of spoken language comprehension that allow multiple sources of information to influence the word recognition process (e.g., Allopenna, Magnuson, & Tanenhaus, 1998; Marslen-Wilson & Tyler, 1980; McClelland & Elman, 1986; Spivey-Knowlton, 1996). Moreover, how frequently subjects looked at distractor objects was a function of the objects' names in the irrelevant language. This fact casts doubt on the possibility that eyetracking results such as these arise from subjects strategically placing the objects' names in a mental buffer upon viewing the display, and then mapping speech input onto that buffer (a kind of word selection) rather than onto the lexicon itself (natural word recognition).

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