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Language Learning and Control in Monolinguals and Bilinguals

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Abstract

Parallel language activation in bilinguals leads to competition between languages. Experience managing this interference may aid novel language learning by improving the ability to suppress competition from known languages. To investigate the effect of bilingualism on the ability to control native-language interference, monolinguals and bilinguals were taught an artificial language designed to elicit between-language competition. Partial activation of interlingual competitors was assessed with eye-tracking and mouse-tracking during a word recognition task in the novel language. Eye-tracking results showed that monolinguals looked at competitors more than bilinguals, and for a longer duration of time. Mouse-tracking results showed that monolinguals' mouse movements were attracted to native-language competitors, whereas bilinguals overcame competitor interference by increasing the activation of target items. Results suggest that bilinguals manage cross-linguistic interference more effectively than monolinguals. We conclude that language interference can affect lexical retrieval, but bilingualism may reduce this interference by facilitating access to a newly learned language.

Keywords: Language processing; Bilingualism; Language interference; Language learning; Eye-tracking; Mouse-tracking

1. Introduction

There is substantial variability in individual ability to acquire a second or third language, and many learners do not achieve native-like proficiency, particularly later in life (Birdsong, 2006, 2009). Successful acquisition depends not only on learning new words and grammar

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but also on the ability to retrieve words from memory during language use. Learning outcomes may be improved by ensuring that words, once acquired, can be retrieved effectively. One obstacle to word retrieval in a new language is competition from similar-sounding words in one's native language. Cross-linguistic interference is common in bilinguals (Bijeljac-Babic, Biardeau, & Grainger, 1997; Duyck, Assche, Drieghe, & Hartsuiker, 2007; van Heuven, Dijkstra, & Grainger, 1998; Schwartz & Kroll, 2006; Voga & Grainger, 2007), and as a result, bilinguals may develop mechanisms to control competition more effectively than monolinguals. We propose that the ability to manage competition from other languages during novel language use is improved in bilinguals relative to monolinguals due to previous linguistic experience.

While listening to speech in a new language, words in other known languages can become activated and compete for selection. Speech unfolds over time, and words that sound similar to the input can become partially activated and interfere with selection of the target word (Allopenna, Magnuson, & Tanenhaus, 1998; Tanenhaus, Magnuson, Dahan, & Chambers, 2000). For example, upon hearing the /k/ at the onset of ''candle,'' an English speaker initially coactivates ''candy'' before converging on the target. If ''candy'' is not suppressed when it becomes inconsistent with the unfolding input, it can interfere with target processing. This interference is especially pronounced when the competitors are of higher lexical frequency than the target (Magnuson, Tanenhaus, Aslin, & Dahan, 2003), as is typically the case when native-language words compete with words in a novel language. If interference from native-language competitors can be mitigated, comprehension in the new language may be improved.

Bilinguals have more potential competitor words to suppress compared to monolinguals; this increase in competitor words may provide bilinguals with more experience managing competition, yielding an advantage in novel-language speech comprehension. Bilinguals activate words that overlap with auditory input in either language (Blumenfeld & Marian, 2007; Marian & Spivey, 2003; Marian, Spivey, & Hirsch, 2003; Spivey & Marian, 1999), so that when a Spanish–English bilingual hears the /k/ sound in ''candle,'' he or she coactivates ''car'' and ''candy'' as an English monolingual would, but he or she also coactivates ''casa'' and ''cabeza'' in Spanish. Word recognition becomes more difficult when the number of competitors increases (Luce & Pisoni, 1998), and bilinguals may adapt to the increased demands by augmenting their ability to suppress irrelevant information. Experience suppressing irrelevant words is thought to contribute to bilinguals' improved cognitive control across the lifespan compared with monolinguals (Bialystok, 1999, 2007; Bialystok, Craik, Klein, & Viswanathan, 2004; Costa, Hernández, & Sebastián-Gallés, 2008). Bilinguals may thus be better equipped to manage native-language interference during novel-language processing, which could facilitate access to novel-language words.

Bilinguals' vocabulary knowledge in a newly learned language surpasses that of monolinguals with comparable training (Cenoz, 2003; Cenoz & Valencia, 1994; Kaushanskaya & Marian, 2009a, 2009b; Keshavarz & Astaneh, 2004; Sanz, 2000; Thomas, 1992; van Hell & Mahn, 1997), but this advantage could be attributed to either better word learning or easier access to learned words in bilinguals. Learning and access are difficult to disentangle, as failure in either step produces the same result—an inability to retrieve the target word. In order to specifically investigate word retrieval in bilingual and monolingual language learners, the present study took a different approach compared with traditional language-learning studies. Instead of comparing bilinguals' and monolinguals' knowledge of a novel language after a fixed training protocol, all participants were trained up to a performance criterion to ensure that novel words had been acquired. Retrieval difficulty was manipulated by testing participants' ability to manage competition between languages during spoken comprehension of the newly learned language. The extent to which competitors interfered with target processing provided an indicator of difficulty in accessing novel language words.

Since lexical access during spoken word comprehension occurs over time, between-language competition was assessed using two online measures of lexical processing: eye-tracking and mouse-tracking. Both techniques can be used to covertly measure how temporal processing of a target is affected by competitors in a visual display. Competing items interfere with target processing because the lexical items they depict resemble the target (e.g., phonological overlap), and this similarity causes participants to visually fixate and manually approach competitors more than unrelated control items.

Eye movements are closely time-locked to relevant features of the input (Cooper, 1974; Tanenhaus et al., 2000) and are executed without conscious awareness. As a result, they have been used extensively to investigate the time courses of both word (Allopenna, Magnuson, & Tanenhaus, 1998; Blumenfeld & Marian, 2007; Marian & Spivey, 2003) and sentence processing (Altmann, 1998; Chambers & Cooke, 2009). However, one limitation of eye-tracking is that visual saccades are inherently all-or-nothing events. Continuous changes in item activation over time are inferred by averaging across multiple discrete looks to candidate objects in a display across trials and participants. In contrast, perceptual-motor hand movements are continuous, graded responses (Freeman & Ambady, 2010) and can be affected by subthreshold processes, so that deviations in smooth trajectories are observed even in the absence of visual saccades to a competitor. It has been shown that movements of the hand are executed contiguously with cognitive processing (Shin & Rosenbaum, 2002), and that fine adjustments can be made in midflight as information about a visual scene is processed (Goodale, Pélisson, & Prablanc, 1986; Song & Nakayama, 2008). The resulting trajectory can be conceptualized as a record of a gradual decision process that converges on one of many attractors in a two-dimensional space (Spivey, Grosjean, & Knoblich, 2005). Although mouse-tracking has only recently been used to inform psycholingusitic processing, it has already proven valuable for investigating the activation of phonological competitors (Spivey et al., 2005), object categorization (Dale, Kehoe, & Spivey, 2007), and aspects of syntactic processing (Farmer, Cargill, Hindy, Dale, & Spivey, 2005).

By combining eye-tracking and mouse-tracking, we are able to investigate the time course and the pattern of cross-linguistic interference and resolution in monolinguals and bilinguals. We predict that bilinguals' extensive experience managing between-language competition and documented cognitive control advantages will improve their ability to manage cross-linguistic interference after learning a novel language. Specifically, it is expected (a) that monolinguals will look at native-language competitors more often and for a longer duration of time than bilinguals, and (b) that monolinguals' mouse-movement trajectories will show more attraction toward native-language competitors relative to those of bilinguals.

Table 1
Monolingual and bilingual participant demographics

	Monolingual English		Bilingual Spanish–English			
Demographics	*M*	*SE*	*M*	*SE*	*t*(22)	*p*
Age (years)	19.75	0.95	25.83	2.94	1.97	ns
Education (years)	13.92	0.64	15.73	0.68	1.94	ns
WASI (performance IQ)	103.33	2.44	103.75	2.22	0.13	ns
WASI (percentile)	58.17	6.05	59.17	5.51	0.12	ns
Digit span (percentile)	72.50	7.91	68.25	5.96	0.43	ns
Nonword repetition (percentile)	46.50	5.79	60.83	6.45	1.65	ns
PPVT-III (percentile)	78.00	4.90	66.33	5.55	1.57	ns
L2 acquisition age (years)			3.83	0.78		
Daily L2 exposure (percentage)			25.33	3.43		
Self-rated L2 speaking proficiency (scale 1–10)			7.25	0.35		
Self-rated L2 reading proficiency (scale 1–10)			7.08	0.44		

Note. L2, second language, according to proficiency; PPVT-III, Peabody Picture Vocabulary Test III; WASI, Weschler Abbreviated Scale of Intelligence.

2. Methods

2.1. Participants

Twelve bilingual Spanish–English speakers and 12 monolingual English speakers completed the experiment. (Four additional participants were tested but were not included in the analyses due to their failure to learn the new language to criterion during the training phase of the study.) Bilinguals had acquired their second language early in life (M = 3.83 years, SE = 0.78) and were highly proficient in both English and Spanish; language history was obtained using the *Language Experience and Proficiency Questionnaire* (Marian, Blumenfeld, & Kaushanskaya, 2007) and is summarized in Table 1. Monolinguals and bilinguals did not differ in performance IQ (*Weschler Abbreviated Scale of Intelligence*, block design and matrix reasoning subtests; PsychCorp, 1999), English vocabulary size (*Peabody Picture Vocabulary Test III*; Dunn & Dunn, 1997), working memory (*Comprehensive Test of Phonological Processing* [CTOPP], digit span subtest; Wagner, Torgesen, & Rashotte, 1999), or phonological working memory (*CTOPP*, nonword repetition subtest), all ps > .05. Bilinguals' Spanish vocabulary was also assessed (*Test de Vocabulario en Imagenes Peabody*; Dunn, Padilla, Lugo, & Dunn, 1986). Participant demographics are summarized in Table 1.

2.2. Stimuli and materials

Stimuli consisted of black-and-white line drawings and represented two-syllable English words with stress on the first syllable; none of the words were English-Spanish cognates. Twenty-four drawings were selected based on high naming consistency norms by native

English speakers (n = 34, none participated in the current study). No participants experienced difficulty in naming the objects in English at the conclusion of the study.

Twenty-four words were created in an artificial language named Colbertian.[1] The words were recorded by a female speaker of Standard American English and were constructed to follow phonotactic rules of English and Spanish. The 24 words did not differ in English and Spanish word likeness ratings by bilingual speakers (n = 5), or in English and Spanish phonological neighborhood size[2] (ps > .05). Each of the 24 pictures was assigned a Colbertian translation, which overlapped phonologically with the English name of another picture (e.g., *acorn* is translated as *shundo*, which overlaps with the English word *shovel*). These overlapping Colbertian–English pairs were used to assess phonological competition between languages; a complete list of all pairings is presented in Appendix A. English competitor words and targets' English translations did not differ (ps > .05) in word frequency (SUBTLEXUS; Brysbaert & New, 2009), concreteness, familiarity, imageability (MRC Psycholinguistic Database; Coltheart, 1981), or number of orthographic (Duyck, Desmet, Verbeke, & Brysbaert, 2004) or phonological (N-Watch; Davis, 2005) neighbors. Targets' Spanish translations and competitors' Spanish translations did not differ (ps > .05) in word frequency (LEXESP; Sebastián-Gallés et al., 1996) or in the number of orthographic or phonological neighbors (BuscaPalabras; Davis & Perea, 2005).

Eye movements were recorded with a head-mounted ISCAN eyetracker system (ISCAN, Inc., Woburn, MA, USA). A scene camera captured the participant's field of view, and an infrared camera allowed the software to track the participant's pupil and corneal reflection. The participant's gaze was indicated by crosshairs superimposed over the scene camera's output and recorded to digital video. Mouse movements, accuracy, and reaction time were recorded using Psyscope (Cohen, MacWhinney, Flatt, & Provost, 1993), which also controlled stimuli presentation.

2.3. Procedure

2.3.1. Learning the new language

The learning paradigm was designed to equate novel language attainment across monolingual and bilingual groups, so that any observed differences in between-language competition could not be attributed to novel-language proficiency. Participants were first familiarized with the 24 pictures and their translations in Colbertian. A picture appeared on a computer screen and 500 ms later the participant heard the Colbertian word over headphones; the participant was instructed to repeat the word aloud. The picture remained on the screen 1,500 ms after audio presentation, and was followed by an intertrial interval of 1,000 ms. The 24 pictures were presented in four random orders. A two-alternative forced-choice recognition test, during which each picture appeared as a target once, ensured that participants were familiar with Colbertian before production training began. In the recognition test, monolinguals and bilinguals did not differ in accuracy or reaction time, ps > .1 (see Table 2).

As production is more difficult than recognition in a new language, participants were trained to produce the Colbertian names of pictures to ensure that their knowledge of the language would be sufficient for the subsequent recognition task testing English

Table 2
Learning the novel language

	Monolingual English		Bilingual Spanish–English		
	M	*SE*	*M*	*SE*	Comparison
Training—Recognition task					
Accuracy (%)	92.10	0.02	95.80	0.01	$t(21) = 1.35$, ns
Reaction time (ms)	2,024	89.7	2,089	65.1	$t(21) = 0.60$, ns
Training—Production task					
First block accuracy (%)	13.54	0.03	25.00	0.05	$t(22) = 1.84, p = .08$
Time to learn (blocks)	15.25	1.23	13.5	1.81	$t(22) = 0.80$, ns

interference. During production training, a picture appeared on the screen and the participant was instructed to name the object aloud in Colbertian. The participant's response was recorded with a microphone. Trials timed out after 4,000 ms without a response. Errors were indicated by a beep over headphones, and all trials were followed by audio presentation of the correct object name. In a single training block each picture appeared once in a random order. Training blocks were repeated until a learning criterion was met (90% of the objects named correctly on two consecutive blocks); monolinguals and bilinguals did not differ in the number of blocks required to reach criterion.[3] Any participant who did not reach criterion after 24 blocks did not advance to the English-interference condition (Fig. 1).

2.3.2. Testing interference from English

After reaching criterion in the new language, between-language competition was assessed. The participant began each trial by clicking in a small box at the bottom of the screen. Target and distractor pictures appeared on the screen, one in the top left and one in

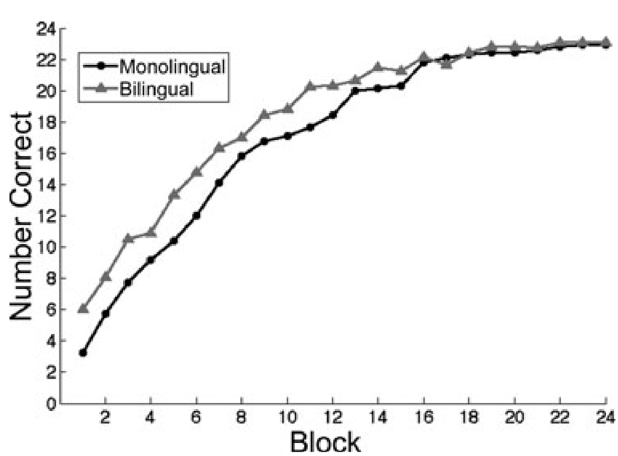

Fig. 1. Monolingual and bilingual performance learning the new language. Within each block, participants attempted to name all 24 items in the new language and received feedback. Blocks were repeated until a learning criterion was reached (90% named correctly on two consecutive blocks). No significant group differences in learning were found after any training block or in final attainment.

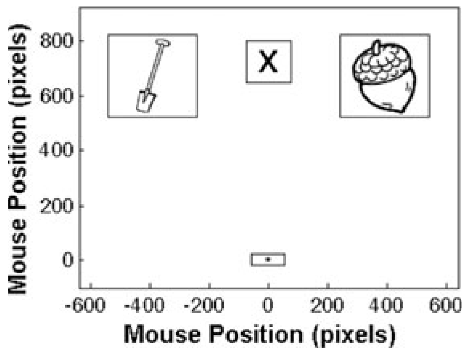

Fig. 2. Sample trial. Participants began each trial by clicking in the small box at the bottom of the screen with an asterisk to reset the mouse cursor position. Upon clicking the box, it disappeared and three boxes appeared at the top of the screen containing a target picture (left or right box), a red ''X'' (center box, used for filler trials), and a phonological competitor or control picture (left or right box, opposite target). At 500 ms after trial onset, the name of the target was spoken in the new language over headphones; the trial ended when the participant clicked in one of the three boxes at the top of the screen.

the top right corner, with target position counterbalanced. A red ''X'' appeared in a box in the top center of the screen (see Fig. 2 for an example trial). After 500 ms, the target word in Colbertian was played over headphones. The participant's instructions were to click the target or, if the target was not present (i.e., filler trials), the red ''X.'' The trial ended when the participant clicked in one of the three boxes.

The target was always a word in Colbertian. In 12 Competitor trials, the English name of the distractor phonologically overlapped with the Colbertian name of the target (e.g., target *shundo* /ʃʌndoʊ/(picture of an acorn) and competitor *shovel* /ʃΛvəl/). In 12 matching Control trials, the same targets were paired with nonoverlapping control items (e.g., target *shundo* /ʃΛndoʊ/and control *mushroom* /mΛʃru:m/). In 24 filler trials, two novel pictures with no Colbertian translation were shown on the screen. The participant heard a word in Colbertian, but the correct response was to click on the red ''X,'' as the word matched neither picture. The names of nontarget objects (e.g., *fummop/shovel* and *panbo/mushroom*) were used in filler trials.

2.4. Data analysis

Eye movements were sampled at 30 Hz and coded for looks to target, competitor, and control pictures from 500 ms preword onset to 2,000 ms postword onset. Mouse position was sampled by the computer at approximately 60 Hz. Incorrect trials were removed from all analyses (1.6% of trials). One monolingual's mouse-tracking and reaction time data were dropped due to recording difficulties. Mouse-tracking trials with a left-target were flipped horizontally across the midline of the screen. In order to average across trials, movement curves were recentered to a common origin (0,0) and normalized for duration (Spivey et al., 2005). Time normalization involved linear interpolation to resample the *x*- and *y*-coordinates of each curve at 101 equally spaced points in time, separately for competitor and control trials.

3. Results

3.1. Eye-tracking

Monolinguals, but not bilinguals, were more likely to fixate between-language competitors than control items, indicating that bilinguals managed competition from a known language more effectively. Time-course analysis revealed that monolinguals looked at competitors more than at control items for a longer duration of time compared with bilinguals, indicating that bilinguals resolved between-language competition earlier. As the minimum latency to execute a saccade in a visual search task falls between 200 and 300 ms (Viviani, 1990), we analyzed the proportion of looks to competitor and control items starting 200 ms postword onset, and ending 1,500 ms postword onset, at which time fixation curves approached an asymptote. Proportion of looks was analyzed with a 2 × 2 (Condition [competitor, control] × Group [monolingual, bilingual]) repeated-measures analysis of variance (ANOVA). The ANOVA revealed a significant main effect of Condition, $F1(1,22) = 5.20$, $p < .05$, partial eta^2 = .086, $F2(1,22) = 3.10$, $p = .08$, partial eta^2 = .033 (Fig. 3), but no main effect of Group, $F1(1,22) = 3.51$, partial eta^2 = .074, $F2(1,22) = 2.47$, partial eta^2 = .026, and no interaction $F1(1,22) = 0.82$, partial eta^2 = .018, $F2(1,22) = 0.88$, partial eta^2 = .009. Planned comparisons[4] indicated that bilinguals did not differ in looks to competitors ($M = 0.49$, $SE = 0.04$) versus controls ($M = 0.44$, $SE = 0.04$), $t(11) = -0.84$, $p > .1$, $d = 0.36$, but monolinguals looked at competitors ($M = 0.62$, $SE = 0.04$) more than at controls ($M = 0.49$, $SE = 0.05$), $t(11) = -2.50$, $p < .05$, $d = 0.83$. Additionally, monolinguals looked at competitors more than bilinguals, $t(22) = 2.08$, $p < .05$, $d = 0.94$ but monolinguals and bilinguals did not differ in looks to controls, $t(22) = 0.65$, $p > .1$, $d = 0.32$.

The time course of competitor activation was examined by calculating eye-tracking fixations in 100 ms time windows starting 500 ms preword onset. Bilinguals (Fig. 4A) showed more looks to competitors than controls continuously from 300 to 700 ms postword onset (all ps < .05). Monolinguals experienced competitor activation for a longer duration of time (Fig. 4B), with more looks to competitors than controls from 200 to 300 ms, 400 to 800 ms,

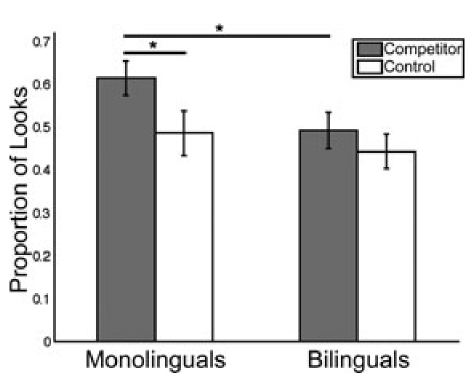

Fig. 3. Proportion of looks to interlingual competitor and control items from 200 to 1,500 ms postword onset. Error bars represent 1 *SE*, and asterisks indicate significance at an alpha of 0.05.

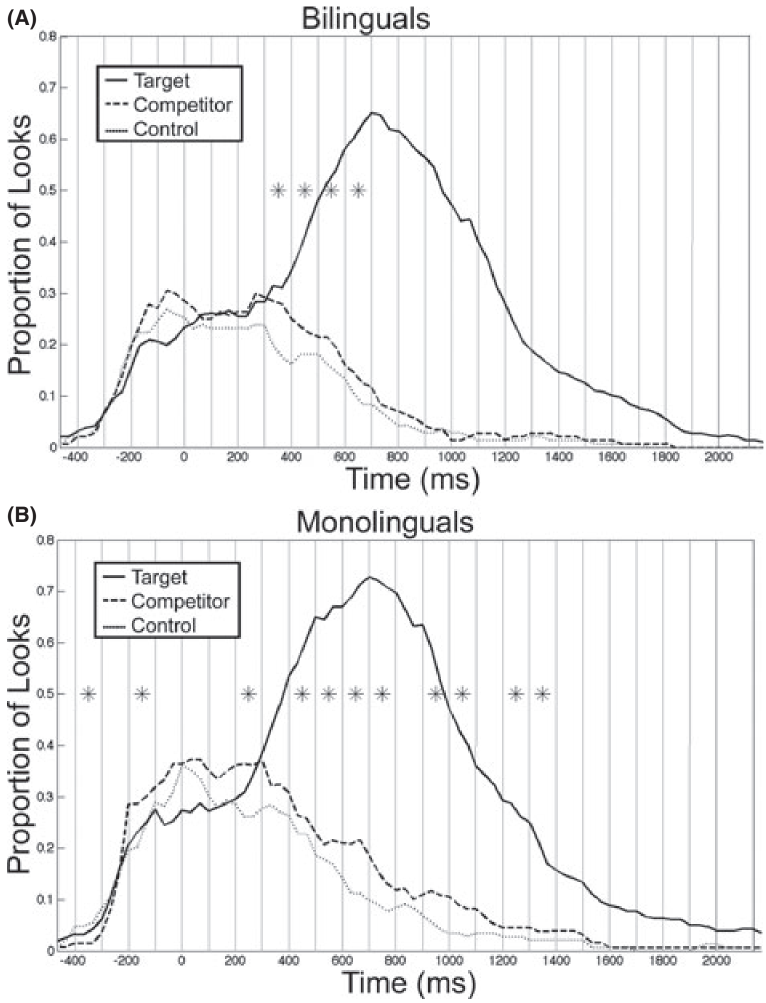

Fig. 4. Bilingual and monolingual eye-tracking fixations. Proportion of looks to competitor and control items were analyzed in 100 ms time windows. (A) Bilinguals looked at competitors more than controls contiguously from 300 to 700 ms postword onset, and (B) monolinguals looked at competitors more than controls at intervals from 200 to 1,400 ms postword onset. Asterisks indicate significance at an alpha of 0.05.

900 to 1,100 ms, and 1,200 to 1,400 ms postword onset (all *p*s < .05). Monolinguals also looked at controls more than at competitors from −400 to −300 ms preword onset, and looked at competitors more than at controls from −200 to −100 ms preword onset (all *p*s < .05). In addition, monolinguals looked at controls more than at targets from −100 ms preword onset to 100 ms postword onset, and they looked at competitors more than at targets from −100 ms preword onset to 200 ms postword onset. Bilinguals looked at controls more than at targets from −500 to −300 ms, and from −100 to 0 ms preword onset, and looked at competitors more than at targets from −200 to 0 ms preword onset. Results suggest that although both groups showed activation of the interlingual competitor, competition

was resolved earlier in bilinguals, indicating that bilingual experience improves the ability to manage cross-linguistic interference.

3.2. Mouse-tracking

Mouse movement curves reliably diverged between competitor and control conditions in both monolinguals and bilinguals. Notably, the effect of the competitor was realized differently between groups. In monolinguals, competition affected the horizontal motion component, thereby disrupting movement toward the target. In bilinguals, the competitor affected vertical motion but did not disrupt target approach, suggesting that language experience affects patterns of cross-linguistic competition. Individual mouse-movement curves were normalized for duration by resampling the time vector at 101 equally spaced intervals and computing *x*- and *y*-coordinate vectors by linear interpolation. The *x*- and *y*-coordinates, representing horizontal and vertical motion, were analyzed separately (Fig. 5). Competitor and control curves were compared with point-to-point *t* tests; a reliable divergence was defined as significant differences on eight consecutive comparisons ($p < .05$) based on a bootstrap criterion from 10,000 simulated experiments (Appendix B; see Dale et al., 2007).

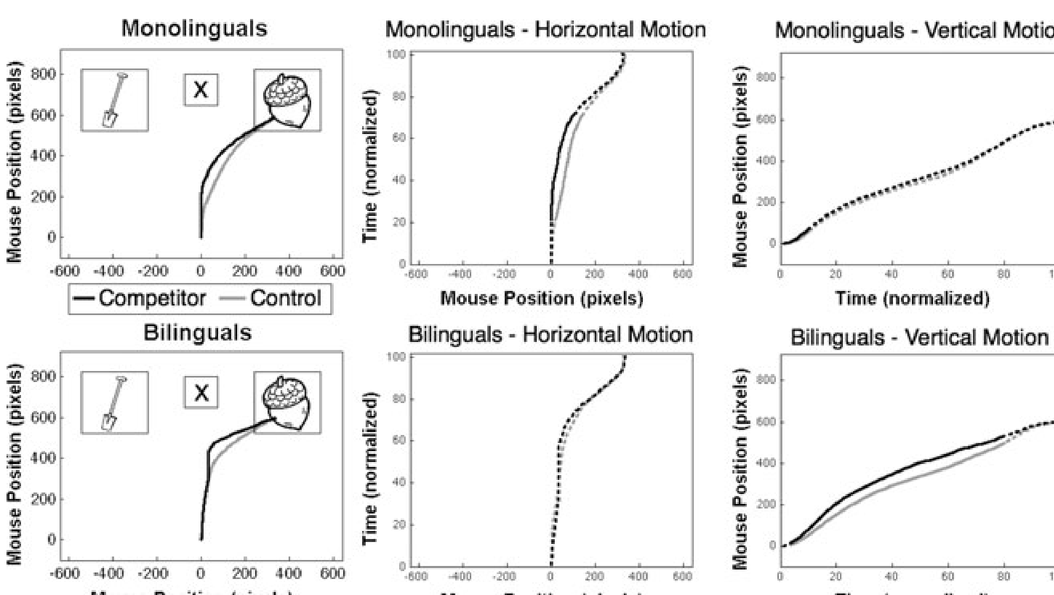

Fig. 5. Results from the mouse-tracking analysis. Lines represent average movement trajectories normalized for duration (left column). The solid line indicates a significant difference between competitor and control curves ($p < .05$); *x* (middle column) and *y* (right column) components of the movement vector were analyzed separately. Bilinguals show no differences in the *x*-coordinate but show a difference in the *y*-coordinate from the 4th to the 80th segment. Monolinguals show a difference in the *x*-coordinate from the 21st to the 72nd of 101 segments, and in the *y*-coordinate from the 2nd to the 10th segments.

Horizontal motion emerges from opposed target- and distractor-attraction, as the attractors pull movement toward opposite sides of the screen (Spivey et al., 2005). When the distractor competes with the target, these opposing influences slow target approach. In monolinguals, competitor and control curves diverged in the *x*-coordinate for 51 consecutive time points (21st–72nd segment, all *p*s < .05), indicating increased competition between the target and the distractor when they overlapped phonologically across languages. Bilinguals did not show an effect of condition on horizontal motion (all *p*s > .05), suggesting that the activations of competitors and controls relative to targets did not differ.

Vertical motion emerges from combined target- and distractor-attraction, as both attractors pull in the same direction (Spivey et al., 2005). Monolinguals' competitor and control curves diverged for eight consecutive time points in the *y*-coordinate (2nd–10th segment, all *p*s < .05), whereas bilinguals' curves diverged for 76 consecutive time points (4th–80th segment, all *p*s < .05), in both cases due to faster movement upward in the competitor condition compared with control. The effect of Condition on vertical motion, but not horizontal motion, in bilinguals suggests that although the *difference* in target and distractor activation was not affected by the presence of a competitor (lack of a horizontal motion effect), there were *equivalent increases* in activation of the target and of the distractor when a competitor was present. This suggests that bilinguals experienced competition between languages, similarly to monolinguals, but were able to successfully manage competition due to an increase in target activation concurrent with the increase in competitor activation. This increase in target activation was sufficient to offset the competitor's pull in the *x*-coordinate. However, the increase in target activation combined with competitor activation had the side effect of increasing overall attraction toward both items in the display (along the *y*-coordinate) compared with the control condition.

3.3. Accuracy and reaction time

Recognition accuracy in the new language was assessed with a 2 × 2 (Condition [competitor, control] × Group [monolingual, bilingual]) repeated-measures ANOVA. No main effects or interactions were found (all *p*s > .1), likely due to near-ceiling performance for both monolinguals and bilinguals, and in both competitor and control conditions (all accuracies above 97.9%).

Reaction times were obtained for response initiation and target selection, and analyzed separately with 2 × 2 (Condition [competitor, control] × Group [monolingual, bilingual]) repeated-measures ANOVAs. No main effects or interactions were found for response initiation (all *p*s > .05), suggesting that groups did not differ in response strategy and approached all trials similarly. A significant main effect of Condition was found for target selection, $F(1,21) = 8.17$, $p < .01$, where competitor trials (M = 1,781 ms, SE = 60 ms) took longer than control trials (M = 1,671 ms, SE = 44 ms), but there was no main effect of Group, $F(1,21) = 0.04$, $p > .1$, and no interaction, $F(1,21) = 1.16$, $p > .1$, suggesting that both groups were affected by the competitor manipulation.

4. Discussion

The aim of this study was to investigate the role of bilingual experience in managing competition between a known language and a newly learned language. Bilinguals were found to resolve between-language competition earlier than monolinguals, and to do so in a manner consistent with a target-facilitation account. Results suggest that bilingual experience affects how novel language learners manage the activation of multiple languages.

Eye-tracking analyses revealed that monolinguals looked at native language competitors more than bilinguals, and that monolinguals looked at competitors more than controls. The time course of activation showed that both monolinguals and bilinguals experienced early activation of the native-language competitor (as soon as 200 ms postword onset), although groups differed in efficiency managing between-language competition. Although bilinguals resolved competitor activation by 700 ms postword onset, monolinguals sustained activation of the competitor up to 1,400 ms postword onset. Differences in competitor processing suggest that bilingual experience affects how interference from nontarget languages is managed, and may contribute to the emergence of executive control advantages typically found in bilinguals (Bialystok, 1999, 2007; Bialystok et al., 2004). The surprising preword-onset differences in looks to targets, competitors, and controls were too early to be related to the auditory stimulus, but may indicate an interaction between visual and linguistic information during language coactivation. Before word onset, the visual input alone may have been sufficient to increase the activation of competitors due to the similarity between the English label of the competitor image and the Colbertian label of the target image. Notably, by 200 ms postword onset (the last point at which fixations may be unaffected by the auditory stimulus, as visual saccades take 200 ms to plan and execute), any early effects had been terminated, suggesting that early effects did not persist to influence processing of the auditory target.

Although eye-tracking showed that monolinguals and bilinguals differed in the time course of between-language competition, mouse-tracking revealed differences in how competition was managed. In monolinguals, increased competitor activation relative to targets curved mouse trajectories away from the target (evidence from horizontal motion). Monolinguals did not move upward on the computer screen more quickly in the competitor condition, indicating that they failed to increase target activation to compensate for the competitor (evidence from vertical motion). In sum, parallel activation of the known language, English, interfered with monolinguals' novel-language processing as between-language cohorts became activated.

In contrast, bilinguals showed no difference in relative activation between conditions, but they did show greater combined activation of the target and distractor during the competitor condition. This suggests greater activation of the competitor compared with the control, concurrent with greater activation of the *target* in the competitor condition compared with the *target* in the control condition. Bilinguals experienced competition from a known language but compensated by facilitating the target. This is consistent with recent findings that the bilingual advantage in executive control stems from improved goal maintenance, and not from active competitor inhibition (Colzato et al., 2008). Overall, the mouse-tracking results suggest that extensive bilingual experience improves the ability to retrieve and process targets despite interference during early novel language learning.

Although eye-tracking and mouse-tracking results both indicated that bilinguals manage between-language competition more effectively than monolinguals, no group differences in reaction time (RT) emerged. As RTs are an outcome-based measure, they are affected both by online processing and by postperceptual decision processes, and this may have obscured the fine-grained temporal dynamics apparent in the eye-tracking and mouse-tracking data. For instance, in addition to managing interference caused by experimental competitors, participants also needed to globally suppress nontarget languages. Bilinguals needed to suppress two other languages during the decision process—the English language that the monolinguals were also suppressing, as well as an entire other language—and this may have obscured group differences in RT.

It is necessary to point out that although there were individual differences in language learning aptitude, these differences were controlled for by using an iterated training paradigm that ended once a proficiency criterion was met. In natural language instruction, where training is constant and final proficiency varies, bilinguals outperform monolinguals in learning novel language vocabulary (Cenoz, 2003; Cenoz & Valencia, 1994; Kaushanskaya & Marian, 2009a, 2009b; Keshavarz & Astaneh, 2004; Sanz, 2000; Thomas, 1992; van Hell & Mahn, 1997), grammar (Klein, 1995; Sanz, 2000; Thomas, 1992), and pragmatic rules (Safont Jorda, 2003). Differences in language transfer (MacWhinney, 2007; Murphy, 2003), metalinguistic awareness (Jessner, 1999, 2008), and phonological working memory (Papagno & Vallar, 1995) are thought to contribute to the bilingual language-learning advantage, but by training participants to a proficiency criterion, the effect of these factors on our results is reduced. We suggest that bilinguals' ability to control interference contributes to their performance advantage in novel language learning by facilitating word retrieval in the target language. This view is supported by recent findings that bilinguals learn a novel language better than monolinguals when the new language contains rules that conflict with the native language (Kaushanskaya & Marian, 2009b). Bilinguals' ability to manage conflict between languages is likely affected by several aspects of bilingual experience, including the age of second language acquisition, first and second language proficiency, and relative language exposure. The precise roles of these factors on the ability to control language interference should be explored in further research.

We have suggested that bilinguals are better than monolinguals at controlling between-language competition, based on both groups experiencing similar competition from the native language and bilinguals being able to manage this competition more effectively. An alternative explanation is that groups manage competition similarly, but bilinguals experience less competition than monolinguals due to decreased native language activation, as each of a bilingual's two languages receive less practice than a monolingual's one. Proficiency in the nontarget language has an important influence on parallel language activation (Blumenfeld & Marian, 2007; Jared & Kroll, 2001; Weber & Cutler, 2004), and it is conceivable that bilinguals coactivated English less than monolinguals, resulting in less interference. In the present study, however, this explanation is not sufficient. Monolinguals and bilinguals did not differ on English vocabulary size ($p > .1$), and although bilinguals' language use was divided between English and Spanish, English use predominated. In addition, the mouse-tracking results suggest that the difference between groups was not strictly one of degree, but also one of kind, and involved changes in how interference was managed. If bilinguals were to experience less competition from English than monolinguals but managed it in a similar way, we would have expected the mouse-tracking curves to look qualitatively similar between groups, but with greater divergence toward the competitor in the monolingual group. Instead, we saw that groups reacted to between-language competition differently, with competitor effects emerging in different movement patterns, suggesting different underlying mechanisms.

In conclusion, we have shown that bilinguals experience less competition from the native language while processing a newly learned language compared with monolinguals. We suggest that interference from other languages is one of the reasons why novel language acquisition is more difficult than first-language acquisition (Birdsong, 2006, 2009; MacWhinney, 2007; Rast, 2010). We propose that previous experience using multiple languages hones the ability to control cross-linguistic competition and improves the processing of words in a newly learned language.

Notes

1. Naming the artificial language simplified explaining the task to participants and made it more engaging. The name *Colbertian* was chosen in reference to media personality and Northwestern University alum Stephen Colbert, who was Homecoming Grand Marshall and Commencement speaker around the time this study was designed and conducted at Northwestern.
2. Phonological neighbors were defined as single phoneme substitutions, deletions, or additions that yielded an English or Spanish word with frequency >0.34 per million (English: SUBTLEXus, Brysbaert & New, 2009; Spanish: LEXESP; Sebastián-Gallés, Martí, Cuetos, & Carreiras, 1996) as per Davis (2005) and Davis and Perea (2005). There was no difference between phonological neighborhood size in English ($M = 0.21$ neighbors, $SE = 0.08$) and Spanish ($M = 0.67$, $SE = 0.35$), $t(23) = 1.52$, $p > .05$.
3. Overall learning in the first block was low due to the difficulty of novel word production in comparison with recognition, which may have reduced our ability to detect an early difference in learning aptitude between groups. There was a trend for bilinguals to correctly name more words in the first training block (see Table 2), and although attainment rate was in the expected direction, the difference was not significant. A consequence of our closed 24-item learning set is that learning rates must decrease over time, as the set of unlearned words shrinks. This flattens attainment curves and minimizes group differences over time.
4. Failure to reject the null on an F test can mask significant pairwise comparisons, a phenomenon referred to as *nonconsonance* (Gabriel, 1969; Hancock & Klockars, 1996; Keppel & Zedeck, 1989). In the current study, planned pairwise comparisons were carried out based on prior visual world eye-tracking studies (Blumenfeld & Marian, 2007; Chambers & Cooke, 2009; Ju & Luce, 2004; Marian & Spivey, 2003; Weber & Cutler, 2004).

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Appendix A

Target words in Colbertian with translations, competitors, and controls

Target (Colbertian)	IPA	Target (English Translation)	Target (Spanish Translation)	Competitor (English)	IPA	Control (English)
acrip	**ˈeɪkrɪp**	easel	caballete	**acorn**	**ˈeɪkɔ:n**	mushroom
appint	**ˈæpɪnt**	iron	plancha	**apple**	**ˈæpəl**	necklace
bakloo	**‘bæklu:**	necklace	collar	**basket**	**‘bæskət**	glasses
cattoss	**ˈkætɑ:s**	pencil	lápiz	**candle**	**ˈkænd**l	iron
caddip	**ˈkedɪp**	elbow	codo	**carrot**	**ˈkerət**	garlic
eazoond	**ˈi:zu:nd**	funnel	embudo	**easel**	**ˈi:zəl**	zipper
eldin	**ˈɛldɪn**	vacuum	aspiradora	**elbow**	**ˈɛl̩boʊ**	scissors
fenip	**‘fenɪp**	carrot	zanahoria	**feather**	**‘feðər**	hammer
fummawp	**ˈfʌmɑ:p**	shovel	pala	**funnel**	**ˈfʌn**l	onion
ganteh	**ˈgɑntə**	scissors	tijera	**garlic**	**ˈgɑɚlɪk**	carrot
glolay	**ˈgloʊle**	apple	manzana	**glasses**	**ˈglæsɛz**	basket
hannawl	**ˈhænɑ:l**	garlic	ajo	**hammer**	**ˈhæmɚ**	feather
iyork	**ˈajɔ:rk**	toilet	inodoro	**iron**	**ˈajɚn**	candle
lateep	**‘læti:p**	hammer	martillo	**ladder**	**‘lædər**	vacuum
munbo	**‘mʌnboʊ**	zipper	cremallera	**mushroom**	**‘mʌʃru:m**	acorn
nepri	**ˈnepri:**	candle	vela	**necklace**	**ˈnekləs**	apple
unyops	**ˈʌnjɑ:ps**	parrot	loro	**onion**	**ˈʌnjən**	funnel
panboe	**ˈpænboʊ**	mushroom	hongo	**parrot**	**ˈpærət**	shovel
peftoo	**ˈpɛftu:**	basket	cesta	**pencil**	**ˈpɛnsəl**	toilet
simmoz	**ˈsɪmɑ:z**	ladder	escalera	**scissors**	**ˈsɪzɚz**	elbow
shundoe	**ˈʃʌndoʊ**	acorn	bellota	**shovel**	**ˈʃʌvəl**	parrot
toymeen	**ˈtoɪmi:n**	glasses	lentes	**toilet**	**ˈtoɪlət**	pencil
vadip	**ˈvædɪp**	feather	pluma	**vacuum**	**ˈvækjuəm**	ladder
zinnul	**ˈzɪnʌl**	onion	cebolla	**zipper**	**ˈzɪpɚ**	easel

Appendix B

To control for alpha-escalation in the point-to-point comparisons of the mouse-tracking results, a minimal reliable sequence of significant comparisons was established with the bootstrapping simulation of Dale et al. (2007). A simulated ''experiment'' was performed 10,000 times for each combination of monolinguals/bilinguals and *x*-/*y*-coordinates. Model participants (11 for the monolingual simulations and 12 for the bilingual simulations) were constructed based on actual group means and standard deviations of the actual movement curves. The competitor and control curves were compared at each time point, and the longest consecutive sequence of significant *t* tests ($p < .05$) was recorded for each simulation. The frequency with which a sequence of length *N* or longer occurred across all simulations was assessed; it was found that a sequence of length 8 occurred with a probability of .01 or lower across all group/coordinate combinations, and was selected as a conservative minimum sequence of significant comparisons.

Sequence frequency in 10,000 simulated experiments for monolinguals and bilinguals and for *X*- and *Y*-coordinates

	ML—*X*		ML—*Y*		BL—*X*		BL—*Y*	
Sequence Size	%	*p*	%	*p*	%	*p*	%	*p*
3	64		3	<.05	4	<.1	25	
4	26		0.2	<.01	0.5	<.01	5	
5	10		0.02	<.001	0.03	<.001	0.7	<.05
6	4		0		0		0.1	<.01
7	1	<.05	0		0		0.03	<.001
8	0.4	<.01	0		0		0	
9	0.1	<.01	0		0		0	
10	0.1		0		0		0	