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Between-Language Competition in Early-Learner Bilinguals

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Between-Language Competition in Early-Learner Bilinguals

A Thesis submitted in partial satisfaction of the requirements
for the degree of Master of Arts

In

Psychological Sciences

By

Cynthia D. Spivey

Committee in charge:

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Professor Teenie Matlock

Matthew Zawadzki

2018

The Thesis of Cynthia D. Spivey is approved, and it is acceptable
in quality and form for publication on microfilm and electronically:

Chair

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2018

DEDICATION PAGE

Dedicated to my wonderful parents, Alice and Dennis,

whose love, support, and encouraging words lifted me up and propelled me

when I felt like I could not move forward on my own. Thank you for believing in me, and

thank you for caring for me on those days that I could barely walk or breathe because

you knew that all I wanted was to get the education that I had always dreamed of.

For my mom, whose sacrifices I am forever grateful for.

I dedicate this to you, you are my hero, and because I am your daughter,

I know that I can accomplish anything.

For my husband, Michael, your unwavering belief that I could do anything, and

insistence that academia needed my perspective, encouraged me to continue on my path.

I am forever grateful for your love and friendship. From the beginning,

you opened up a world to me that I had never dreamed of.

TABLE OF CONTENTS

LIST OF FIGURES

Acknowledgements

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ABSTRACT

Master's Thesis Title: Between-Language Competition in Early-Learner Bilinguals
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To better understand the neural and cognitive functions of bilingual brains, recent research has begun to study both the general cognitive abilities of bilinguals and the real-time language processes of bilinguals. Findings suggest that, while bilinguals may enjoy benefits in executive control of cognitive function (compared to monolinguals), they also may suffer certain deficits in lexical retrieval as a result of two lexicons competing against one another. Much of the research examining bilinguals' real-time language comprehension has used bilinguals who learned their second language after puberty, as it can be difficult in certain areas to find a sizeable population of native bilinguals (who learned both languages as children). In the present study, three language comprehension experiments record the eye movements of late-learner bilinguals, early-learner bilinguals, and monolinguals (as a control condition) during the processing of English and Spanish spoken instructions. Results replicate the mild deficit in lexical processing that late-learner bilinguals exhibit (e.g., competition between the two lexicons for recognizing a spoken word in one of the languages). However, it appears that early-learner bilinguals do not to exhibit this mild deficit. Discussion concludes that in order to enjoy the cognitive benefits of bilingualism and avoid the lexical processing deficits; bilinguals should learn both languages as early as possible.

Introduction

With an ever-increasing bilingual population all over world, there has been heightened focus on research investigating bilingualism. In the fields of cognitive science, psycholinguistics, and neuroscience, researchers have studied the processes of the bilingual mind to better understand how a bilingual speaker manages two or more language systems, and how these language systems interact. Studies comparing bilinguals to monolinguals investigate to what degree bilinguals' cognitive and linguistic abilities vary from those who know only one language. What intrinsic mechanisms account for differences in linguistic processing between monolinguals and bilinguals? Is linguistic processing the same for all bilinguals, or are there also differences due to time of acquisition of both languages? In comparison to monolingual language research, the investigation of bilingualism provides researchers a more comprehensive platform to better understand the capacity of the human brain in terms of language processing.

Research focused on the cognitive and linguistic processing of bilinguals is fairly recent; nevertheless, several studies have emerged that illustrate differences between monolingual and multilingual speakers. Early research by Ben Zeev (1977) found that bilingual Hebrew-English speaking children displayed greater cognitive flexibility in terms of syntactic rule usage and more advanced problem-solving skills as compared to monolingual children. In addition to increased problem-solving skills and greater metalinguistic awareness (Jessner, 2008), Bialystok (1999) found that bilingual children displayed greater attentional control during difficult problem solving tasks than their monolingual counterparts in a non-verbal card sort task. Similar to Bialystok's (1999) findings on bilingual children, Bialystok and colleagues (2008) reported that older adult bilinguals exhibited greater attentional control than their monolingual counterparts during a Simon Task. This finding may suggest that bilingualism provides some protection against the decline of executive control functions that often comes with aging (Bialystok, et al., 2008). Results have also pointed to bilinguals having increased efficiency in switching between mental sets (Prior & MacWhinney, 2010). Neuroimaging studies have also revealed that areas of the brain that are involved in executive functioning are also involved a bilingual's dual language processing (Abutalebi & Green, 2008; Garbin et al., 2010). The research illustrating advantages in the bilingual domain all indicate possible advantages in executive function processes such as attentional control, cognitive inhibition, inhibitory control, working memory, and cognitive flexibility.

Studies of bilingualism have also investigated tasks that activate lexical knowledge or lexical retrieval, with results pointing to a deficit in bilingual lexical access compared to monolinguals (Soares, & Grosjean, 1984). For example, Soares and Grosjean's (1984) results suggest bilinguals have slower reading times for mixed language, or code-switched, sentences than monolinguals in a phoneme triggered lexical decision task. Other early research investigating lexical retrieval also found that bilinguals had slower response times than monolingual speakers in mixed language tasks where their second language was the target language (Scarborough, et al., 1984). Research investigating a bilingual's deficit in lexical access has not been limited to reading or word identification. Under the assumption that picture naming required lexical knowledge of the target language, Gollan, Montoya, Fennema-Notestine & Morris (2005) reported that bilinguals made more mistakes in a picture-naming task, and were much slower than their monolingual counterparts when naming pictures in their dominant language. As illustrated in the above research, speakers of more than one language may have disadvantages, compared to speakers of one language, when accessing the target language for the task at hand.

One question central to bilingual language research is the representation of lexical items in a bilingual's language system. Some have argued that the two languages are organized into two separate lexicons, and are accessed independently of each other (MacNamara & Kushnir, 1971; Scarborough et al., 1984; Soares & Grosjean, 1984). In contrast to the aforementioned "separate-lexicon model" (Gerard & Scarborough, 1989), other researchers argue for the simultaneous activation of both languages (Green, 1986; Bijeljac-Babic, Biardeau & Grainger, 1997; Blumenfeld & Marian, 2007; Ju & Luce, 2004; Spivey & Marian, 1999). For example, in an eye-tracking experiment, Spivey and Marian (1999) found that when Russian-English bilinguals were presented with a spoken target word in one language (e.g., "marker"), they often looked briefly at a distractor object whose name in the *other* language was phonetically similar to the target word (e.g., a postage stamp, called "marka" in Russian). Thus, as the spoken English word "marker" unfolds over the course of a few hundred milliseconds, the bilingual listener's Russian language system experienced some brief partial activation of the lexical representation for "marka." (See also Allopenna, Magnuson & Tanenhaus, 1997, for similar examples of monolingual lexical competition). Eye fixations of those interlingual distractor objects were reliably more frequent than eye fixations to control distractor objects (with no phonetic similarity). This finding suggests that bilinguals experience simultaneous activation of both languages even while listening to only one of them.

Research investigating parallel activation of a bilingual's languages during spoken word recognition has demonstrated that late bilinguals tend to show greater interference/competition from words in their first language while listening to their second language, and somewhat less interference from words in their second language while listening to their first language (Marian & Spivey, 2003). When these Russian-English participants were put into a "monolingual mode" of speaking their native Russian language (with Russian music in the background, a native Russian experimenter, and a consent form all in Russian), these late-learner bilinguals no longer fixated the phonetically similar interlingual distractor objects at a greater frequency than the control distractor objects, thus exhibiting less competition from their second language. This finding is particularly interesting because it demonstrates that competition between and within languages is not the same across a bilingual's first and second language. In bilingual research, Genesee et al., (1978) makes a distinction between "early" and "late" bilinguals, the former as those who learn both languages simultaneously from birth, and the latter as bilinguals who become bilingual at school age or later on. In research, specifying bilinguals as early or late implies differences in processing, as age of acquisition may affect how a bilingual's two linguistic systems interact (Genesee et al., 1978; Butler & Hakuta, 2004; Fabbro, 2001; Perani et al., 2003). To further illustrate distinctions between early and late bilinguals, in an fMRI study on how multiple languages are represented in the human brain, Kim, Relkin, Lee, and Hirsch (1997) found that late-learner bilinguals have different cortical regions associated with use of their two languages, whereas early-learner bilinguals have the same cortical regions associated with their two languages. What we do not know is, how do those differences in cortical representation affect language processing in early-learner bilinguals when compared to late-learner bilinguals?

In the bilingual domain, headband-mounted eyetracking methodologies have enabled researchers to study spoken language processing in bilinguals in a way that couples both visual and linguistic input (Marian, & Spivey, 2003). The advantage of using this methodology is that eyetracking devices are able to record a person's eye movements and allow for a millisecond-by-millisecond measure of attention (Magnuson, Tanenhaus, Aslin, & Dahan, 1999). This paradigm does not require participants to make metacognitive decisions about the information that is being presented to them because eye movements are tracked while they spontaneously respond to spoken language in an ecological valid fashion (Magnuson, et al., 1999; see also Bartolotti & Marian, 2013).

In the present study, three eyetracking experiments were conducted to examine competition between languages in early-learner and late-learner bilinguals. Parallel activation of both languages in bilingual speakers, and the resulting interlingual competition between lexical representations (e.g., Bijeljac-Babic, et al., 1997; Spivey & Marian, 1999; Marian & Spivey, 2003), may be more pronounced in bilingual speakers who learned their second language somewhat later in life, and thus may have somewhat separate cortical regions carrying out their two different language processes (Kim et al., 1997, Fabbro, 2001). By contrast, early-learner bilinguals have greater experience managing two language systems, as compared to late-learner bilinguals, which may result in greater cognitive control when inhibiting one language over the other. This ability to better suppress one language while using the other may make early-learner bilinguals better able to manage any cross-linguistic competition. In this study, we predict that early-learner bilingual speakers' two languages may interfere less with one another due to both languages being learned in tandem and becoming more adept at switching between one another. Thus, early-learner bilingual speakers' two languages may show less between-language competition than late-learner bilingual speakers due to both languages being learned equally (and coextensive in their cortical regions) as result of simultaneous language learning onset. Following this prediction, we expect that late-learner bilinguals will look at interlingual-competitor distractor objects more frequently than control distractor objects (e.g., Marian & Spivey, 2003), but early-learner bilinguals may not exhibit this difference. That is, early-learner bilinguals may be able to cognitively manage their two language systems so efficiently that the name of the interlingual distractor object in one language will not significantly interfere with their spoken word recognition in their other language.

Experiment 1 recorded the eye movements of early-learner and late-learner Spanish-English bilinguals with spoken English instructions (the second language of the late-learners). Experiment 2 recorded the eye movements of early-learner and late-learner Spanish-English bilinguals with spoken Spanish instructions (the native language of the late-learners). Finally, Experiment 3 recorded the eye movements of monolingual English speakers with the same visual stimuli, and the same spoken

English instructions, as Experiment 1. This monolingual version of the experiment serves as a control group to ensure that the interlingual distractor objects used in Experiment 1 (whose Spanish names these monolingual English speakers do not know) are not intrinsically more visually distracting than the target objects.

Experiment 1

In Experiment 1, early and late-learner Spanish-English bilinguals were tested in English to examine spoken language processing under two conditions: (a) a between-language competitor condition, where the Spanish name of a distractor object shared phonetic overlap with the spoken English target word, and (b) a no-competition control condition, where the distractor object shared little or no phonetic overlap, in either language, with the spoken English target word.

Methods

Participants. Nineteen undergraduate students from the University of California, Merced participated in this study in exchange for participation credit for a course requirement. Of the nineteen student participants, ten were Spanish-English early bilingual speakers, and nine were Spanish-English late bilingual speakers. The Language Experience and Proficiency Questionnaire (Marian, Blumenfeld, & Kaushanskaya, 2007) was administered to all participants to obtain language history information. Research has indicated that specifying bilinguals as early or late implies differences in both processing and cortical representation, as age of acquisition may affect how a bilingual's two linguistic systems interact (Genesee et al., 1978; Butler & Hakuta, 2004; Fabbro, 2001; Perani et al., 2003). In the current study, bilingual language speakers that learned both of their languages before the age of 7 are considered early-learner bilinguals, and bilingual language speakers that acquired their second language after the age of 7 are considered late-learner bilinguals (Fabbro, 2001). Therefore, we used the language history information obtained from participants' LEAP-Q (Language Experience and Proficiency Questionnaire) to divide the Spanish-English bilingual participants into two groups based on age of acquisition of each of their languages. Of the 19 bilingual speakers, 10 were characterized as early-learner bilinguals (bilinguals that learned both their languages before the age of 7), and the remaining 9 Spanish-English bilinguals were characterized as late-learner bilinguals that became fluent in their second language after the age of 7 (Fabbro, 2001). Six bilingual participants were not included in the analyses due to their answers on the LEAP-Q not permitting a clear designation as either early or late bilingual. We only included late bilinguals whose native language was Spanish. In order to keep our late-learner bilingual population as homogenous as possible, late bilinguals whose native language was English were not included in this study.

Apparatus. Eye movements were recorded using an Eyelink II head-mounted eyetracker. The eyetracker has three cameras mounted on the headband. Two cameras allow for the eyetracking of both eyes, while the third camera tracks the frame of the stimulus display screen, so that point of gaze can be mapped to stimuli in terms of their pixel coordinates of the computer display screen. The Eyelink II uses corneal reflection and dark pupil tracking to obtain a track of eye position with accuracy to within 0.5 degrees of visual angle.

Design. All participants wore the headband-mounted eyetracker while they heard a spoken English word and were asked to move a computer mouse to the corresponding picture in a visual array. The experiment consisted of two between-subjects conditions: early-learner bilinguals and late-learner bilinguals. And it consisted of two within-subjects conditions: a between-language competition condition (with an interlingual distractor object) and a no-competition control condition (with a neutral distractor object).

In the between-language competitor condition, one object in the display was the target object (e.g., a bowl), the English name of which was heard spoken over headphones. Also in the display was the between-language competitor object, whose name in Spanish overlapped with the phonetic properties of the word spoken in English (e.g., a picture of a wedding, called "boda" in Spanish). Neither the English name nor the Spanish name for the interlingual competitor distractor object was ever spoken within a participant's experimental session. For example, in the between-language competition condition, a participant would hear the word "bowl" and would see on the right side of the computer screen a picture of a bowl, and also a see a picture of a wedding on the left side of the computer screen. The target is the picture of the bowl, but the Spanish word for wedding, "boda", has phonetic similarities with the English word "bowl," and thus may elicit competition between languages for bilingual speakers. That is, upon hearing the English word "bowl," partial activation of the lexical representation for "boda" in these bilinguals may trigger brief eye movements to the picture of the wedding.

In the no-competition control condition, one object was the target object (e.g., bowl), and the distractor was a control object whose name had no phonetic overlap with the commonly accepted term for the target object in either language (e.g., a cake, or "pastel" in Spanish). Targets in this condition were the same targets used in the between-language competitor condition, but here, the targets were paired with distractor objects that had no phonetic overlap with the target object. For example, in the no-competition control condition, a participant would hear the word "bowl" and would see on the right side of the computer screen a picture of a bowl and also a see a picture of a cake on the left side of the computer screen. There should not be any competition between languages for bilingual speakers in this condition.

In filler trials, a filler-trial display contained objects that were not presented in the other trial types and whose names shared no phonetic similarity in either language (filler trials). Filler trials were used to prevent participants from explicitly noticing the occasional phonetic similarity among some object names in the two main conditions. In one filler trial, for example, a filler target was "fish" and filler distractor object was a kite (or "cometa" in Spanish).

Each participant's eye movements were recorded across 40 trials: 8 control trials (with a neutral distractor object), 8 between-language competitor trials (with an interlingual distractor object), and 24 filler trials (to prevent participants from discovering the linguistic manipulation). For each participant, trial sequence was randomly generated, with 8 target-competitor trials (e.g, bowl and boda, etc.), randomly selected from the full set of 16 (see Appendix A), along with their corresponding 8 target-control trials included as well (e.g., bowl and chair). The various competitor and target objects were located in the top right and left corners of the computer display screen. These fixed locations allowed us to compare eye movements to competitors and targets by examining fixations or looks to a specific location within a display.

Materials. A complete list of all target items, between-language competitors, and control distractors can be found in Appendix A. Stimuli consisted of 120 color jpeg images of objects that had common names between one and four syllables long in both languages. Two pictures were presented in each trial display (a target object and a distractor object). Thirty-two of these displays were used to compare the between-language competition condition with the control condition (with each participant seeing 8 between-language competition displays and their 8 matched control displays). The remaining images of objects were designated filler objects for filler trials that help prevent participants from discovering the linguistic manipulation.

For each trial, images of objects were presented in the top left and top right of the display screen, and the mouse cursor began at the bottom center of the screen. When the participant clicked the start box at the bottom, there was a 500ms pause and then the spoken target word was delivered over headphones. For these English trials, a female monolingual English speaker recorded the spoken stimuli.

Procedure. Upon arrival to the lab, participants were greeted by English-speaking research assistants. All participants were asked to fill out both a consent form and a language questionnaire. Before experiment began, participants were instructed to be seated in front of a computer screen, with tips of toes arranged on blue tape on the carpet. Participants were then asked to make sure that both feet were placed firmly on the floor, to ensure a standard viewing distance of about 60cm from the computer screen. After the participant was seated, the eyetracker was calibrated, headphones were placed on the participant's head, and the participant was instructed to place their hand on computer mouse. Each participant was presented with 40 trials: 8 control trials: 8 between-language competitor trials, and 24 filler trials. At the start of each trial, over headphones the participant was instructed to look at the two crosshairs on the computer screen, then the trial would begin. Two pictures were presented in each display (a target object that would get referred to with a spoken English word, and a distractor object that might be an interlingual competitor or a neutral control). At the end of experiment, participants were asked to fill out a form that asked what they believed the experiment was testing. This was to ensure that participants had not recognized that some words had similarities, in which case, that participant would be removed from analyses. No participant recognized any similarities between words in the experiment.

Analyses. Eye movements were sampled at 250 Hz and coded for number of looks to distractor objects (either the interlingual cohort object in the between-language competitor condition or the control object in the no-competition control condition). The mean number of fixations to the interlingual distractor object in the between-language competition condition was compared to the mean number of fixations to the control distractor object (whose name had no phonetic overlap in either language with the commonly accepted term for the target object) in the no-competition control condition. To analyze the data, a two-way analysis of variance (ANOVA) was performed, using Language Experience (Early bilingual vs. Late bilingual), and Distractor Object (Competitor vs. Control) as independent variables, and Number of Looks to the Distractor Object as the dependent variable.

Results and Discussion

The ANOVA revealed a main effect of early bilinguals making slightly more fixations of all distractor objects (M=1.40) than late bilinguals (M=1.11); $F(1,34)=8.093$, $p < .01$. There was also a main effect of the between-language distractor object drawing more eye fixations (M=1.38) than the neutral control distractor object did (M=1.13); $F(1,34)= 6.026$, $p < .02$. However, the interaction between these two factors (as seen in Figure 1) revealed that the effect of distractor type was present only in the late bilinguals; $F(1,34)=5.077$, $p<.05$. Planned pairwise comparisons were then performed to determine the effect of the between-language distractor object in the late bilinguals, and also in the early bilinguals. Among the late bilinguals, the difference between looks to the between-language competitor (M=1.35) and looks to the control object (M=0.87) was statistically robust; $t(8)=4.32$, $p<.01$. In contrast, among the early bilinguals, the difference between looks to the between-language competitor (M=1.41) and looks to the control object (M=1.39) did not approach significance; $t(9)=0.1$, $p>.5$.

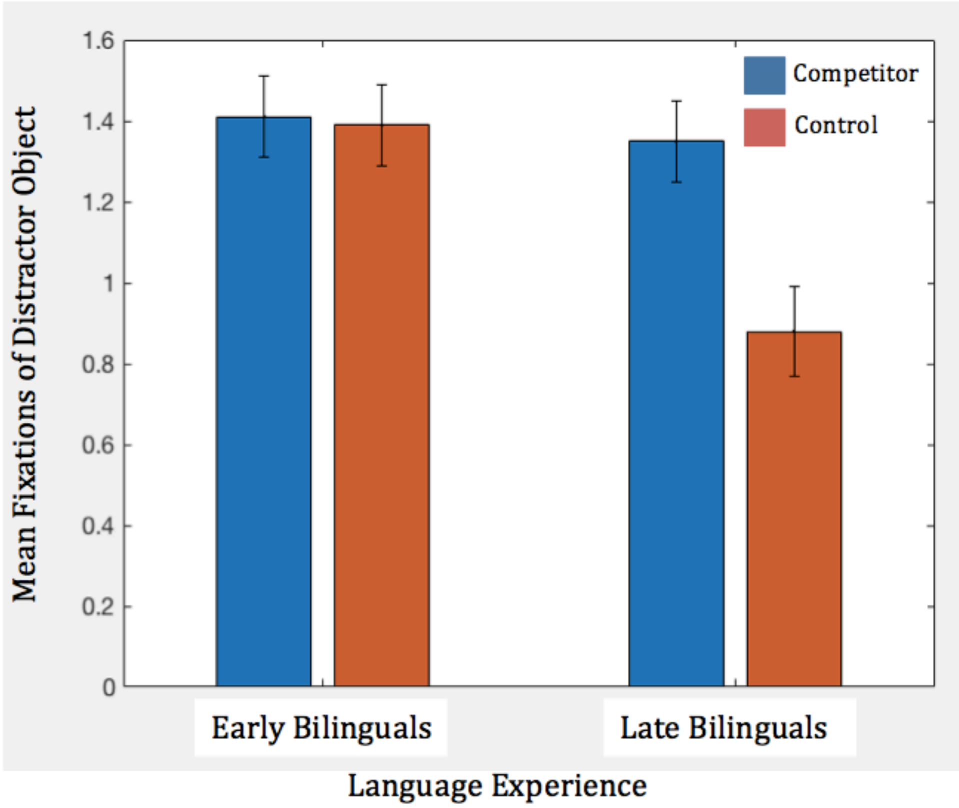

Figure 1. While early bilinguals showed no difference between types of distractors, late bilinguals made substantially more eye movements to the interlingual competitor distractor object than to the control distractor object. (Error bars represent +/- 1 SE.)

Thus, in this English-instruction experiment, *late* Spanish-English bilinguals made more eye movements to the distractor object when it was an interlingual competitor (with similar phonetic pronunciation as target object) than when it was a neutral control object (with no phonetic similarity in either language). For instance, when instructed to click the "peanut," late bilinguals made frequent eye movements to the picture of a pineapple ("piña" in Spanish), but rarely looked at the picture of a heart ("corazón" in Spanish). However, with *early* Spanish-English bilinguals, a different pattern emerged. They produced about the same number of looks to distractor objects whether they were interlingual distractors as when they were neutral control distractors. When told to click the "peanut" in English, early bilingual subjects were no more likely to look at a pineapple than they were to look at a heart. These results suggest that while late bilinguals exhibit some brief competition and/or interference between their two language subsystems (e.g., Marian & Spivey 2003; Ju & Luce, 2004), early bilinguals may have sufficient cognitive efficiency at using their two language subsystems that this competition/interference is minimal.

Experiment 2

Experiment 2 was similar to Experiment 1, except that the spoken instructions were delivered in Spanish. In Experiment 2, a different group of early and late-learner Spanish-English bilinguals were tested in Spanish to examine spoken language processing under two conditions: (a) a between-language competitor condition, where the English name of a distractor object shared phonetic overlap with the spoken Spanish target word, and (b) a no-competition control condition, where the distractor object share little or no phonetic overlap, in either language, with the spoken Spanish target word.

Method

Participants. Twenty-seven undergraduate students from the University of California, Merced participated in this study in exchange for participation credit for a course requirement. Of the twenty-seven student participants, eighteen were Spanish-English early bilingual speakers, and nine were Spanish-English late bilingual speakers. The Language Experience and Proficiency Questionnaire (Marian, Blumenfeld, & Kaushanskaya, 2007) was administered to all participants to obtain language history information. Research has indicated that specifying bilinguals as early or late implies differences in both processing and cortical representation, as age of acquisition may affect how a bilingual's two linguistic systems interact (Genesee et al., 1978; Butler & Hakuta, 2004; Fabbro, 2001; Perani et al., 2003). In the current study, bilingual language speakers that learned both of their languages before the age of 7 are considered early-learner bilinguals, and bilingual language speakers that acquired their second language after the age of 7 are considered late-learner bilinguals (Fabbro, 2001). Therefore, we used the language history information obtained from participants' LEAP-Q (Language Experience and Proficiency Questionnaire) to divide the Spanish-English bilingual participants into two groups based on age of acquisition of each of their languages. Of the 27 bilingual speakers, 18 were characterized as early-learner bilinguals (bilinguals that learned both their languages before the age of 7), and 9 were characterized as late-learner bilinguals that became fluent in their second language after the age of 7 (Fabbro, 2001). We only included late bilinguals whose native language was Spanish. Late bilinguals whose native language was English were not included in this study.

Apparatus. Eye movements were recorded using an Eyelink II head-mounted eyetracker. The eyetracker has three cameras mounted on the headband. Two cameras allow for the eyetracking of both eyes, while the third camera tracks the frame of the stimulus display screen, so that point of gaze can be mapped to stimuli in terms of their pixel coordinates of the computer display screen. The Eyelink II uses corneal reflection and dark pupil tracking to obtain a track of eye position with accuracy to within 0.5 degrees of visual angle.

Design. Eye movements were recorded using the same Eyelink II head-mounted eyetracker as in Experiment 1. All participants wore the headband-mounted eyetracker while they heard a spoken word in Spanish and were asked to move a computer mouse to the corresponding picture in a visual array. The experiment consisted of two between-subjects conditions: early-learner bilinguals and late-learner bilinguals. And it consisted of two within-subjects conditions: a between-language competition condition (with an interlingual distractor object) and a no-competition control condition (with a neutral distractor object).

In the between-language competitor condition, one object in the display was the target object (e.g., a pineapple), the Spanish name of which ("piña") was heard spoken over headphones. Also in the display was the between-language competitor object (e.g., a peanut), whose name in English language overlapped with the phonetic properties of the spoken Spanish target word. The name of the between-language competitor object was never spoken in either language during a given participant's experimental session. For example, in the target-competitor present condition, a participant would hear the word "piña" and would see on the right side of the computer screen a picture of a pineapple and also a see a picture of a peanut on the left side of the computer screen. The target is the picture of the pineapple, but the Spanish name for the English word "pineapple", which is "piña", has phonetic similarities to the English word "peanut" and may elicit competition between languages for bilingual speakers, potentially resulting in one or two eye movements to the peanut.

In the no-competition control condition, one object was the target object (e.g., "piña", or pineapple in English), and the other was a control object whose name had no phonetic overlap with the commonly accepted term for the target object in either language (e.g., a heart, or "corazón" in Spanish). Targets in this condition were the same targets used in the between-language competitor condition, but here, the targets were paired with distractor objects that had no phonetic overlap with the target object.

In filler trials, a filler-trial display contained objects that were not presented in the other trial types and whose names shared no phonetic similarity in either language (filler trials). Filler trials were used to prevent participants from explicitly noticing the occasional phonetic similarity among some object names in the two main conditions. In the filler trials, for example, a filler target might be "abeja", the Spanish word for "bee", and a filler distractor object was a fish ("pescado" in Spanish).

Each participant's eye movements were recorded across 40 trials: 8 control trials (with a neutral distractor object), 8 between-language competitor trials (with an interlingual distractor object), and 24 filler trials (to prevent participants from discovering the linguistic manipulation). For each participant, trial sequence was randomly generated, with 8 target-competitor trials (e.g, piña and peanut, etc.), randomly selected from the full set of 16 (see Appendix B), along with their corresponding 8 target-control trials included as well (e.g., piña and heart). The various competitor and target objects were located in the top right and left corners of the computer display screen. These fixed locations allowed us to compare eye movements to competitors and targets by examining fixations or looks to a specific location within a display.

Materials. A complete list of all target items, between-language competitors, and fillers can be found in the appendices. Stimuli consisted of 120 color jpeg images of objects that had common, names between one and four syllables long in both languages. Two pictures were presented in each trial display (a target object and a distractor object). Thirty-two of these displays were used to compare the between-language competition condition with the control condition (with each participant seeing 8 between-language competition displays and their 8 matched control displays). The remaining images of objects were designated filler objects for filler trials that help prevent participants from discovering the linguistic manipulation.

For each trial, images of objects were presented in the top left and top right of the display screen, and the mouse cursor began at the bottom center of the screen. When the participant clicked the start box at the bottom, there was a 500ms pause and then the spoken target word was delivered over headphones. For these Spanish trials, a female bilingual Spanish speaker recorded the spoken stimuli.

Procedure. Upon arrival to the lab, participants were greeted by English-speaking research assistants. All participants were asked to fill out both a consent form and a language questionnaire. Participants were instructed to be seated in front of a computer screen, with tips of toes arranged on blue tape on the carpet, and asked to make sure both feet were firmly on the floor. After subject was seated, the eyetracker was calibrated, headphones were placed on participant's head, and participant was instructed to place hand on computer mouse. Each participant was presented with 40 trials: 8 control trials: 8 between-language competitor trials, and 24 filler trials. At the start of each trial, over headphones participant was instructed to look at the two crosshairs on the computer screen, then trial would begin. Two pictures were presented in each trial display (a target object that would get referred to with a spoken Spanish word, and a distractor object that might be an interlingual competitor or a neutral control). At the end of experiment, participants were asked to fill out a form that asked what they believed the experiment was testing. This was to ensure that participants had not recognized that some words had similarities, in which case, that participant would be removed from analyses. No participant recognized any similarities between words in the experiment.

Analyses. Eye movements were sampled at 250 Hz and coded for number of looks to distractor objects (either the interlingual cohort object in the between-language competitor condition or the control object in the no-competition control condition). The mean number of fixations to the interlingual distractor object in the between-language competition condition was compared to the mean number of fixations to the control distractor object (whose name had no phonetic overlap in either language with the commonly accepted term for the target object) in the no-competition control condition. To analyze the data, a two-way analysis of variance (ANOVA) was performed, using Language Experience (Early bilingual vs. Late bilingual), and Distractor Object (Competitor vs. Control) as independent variables, and Number of Looks to the Distractor Object as the dependent variable.

Results and Discussion

The mean fixations to interlingual competitor items were compared to the mean fixations to control items. In contrast to Experiment 1, the main effect of Language

Experience here was only marginally significant; F(1,50)=2.744, p =.1. With these Spanish instructions, it was late bilinguals who made slightly more fixations of all distractor objects (M=1.58) than did early bilinguals (M=1.37). Similar to Experiment 1, there was again a robust main effect of Distractor Object, F(1,50)=8.786, p < .01. Interlingual distractor objects were looked at more frequently than control distractor objects. Notably, the interaction between these two factors, which was significant in Experiment 1, was not significant here; F(1,50)=1.201, p>.1. However, as can be seen in Figure 2, the magnitude of the Distractor Object effect among late bilinguals is approximately twice the size of that among the early bilinguals. As was conducted in Experiment 1, planned pairwise comparisons were performed to determine the effect of the interlingual distractor object in the late bilinguals, and also in the early bilinguals. Among the late bilinguals, the difference between looks to the interlingual competitor (M=1.84) and looks to the control object (M=1.32) was statistically robust; t(8)=4.57, p<.01. In contrast, among the early bilinguals, the difference between looks to the interlingual competitor (M=1.48) and looks to the control object (M=1.25) was only marginally significant; t(17)=1.9, p<.1.

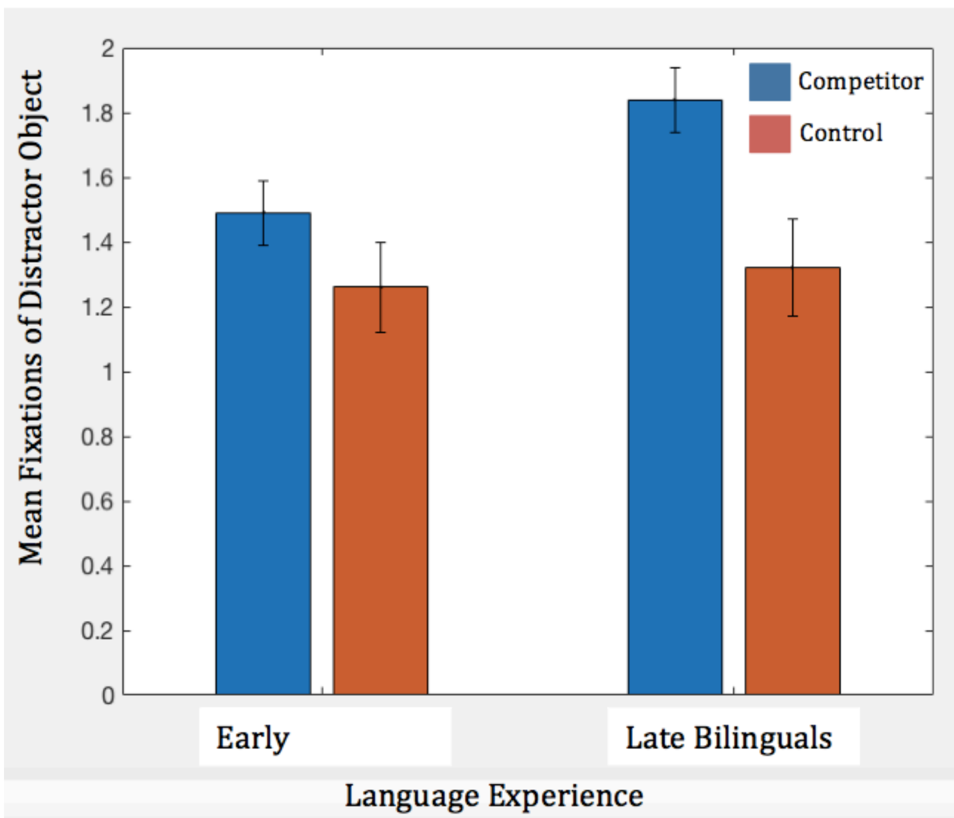

Figure 2. While early bilinguals showed a small, only marginally-significant, difference between types of distractors, late bilinguals made significantly more eye movements to the interlingual competitor distractor object than to the control distractor object. (Error bars represent +/- 1 SE.)

In this Spanish-instruction experiment, there is some suggestive evidence that early-learner bilingual subjects were slightly prone to make eye movements to incorrect objects when the display contained an interlingual distractor (i.e., a competitor object with similar phonetic pronunciation in English as the target object's name in Spanish). For example, early bilingual subjects were occasionally looking at the peanut when told to click the "piña" in Spanish. However, this effect is only marginally significant when compared the control condition with a neutral distractor object. Late bilingual subjects, by contrast, were much more likely to make eye movements to incorrect objects when a between-language distractor object was present in the display. For instance, late bilingual subjects frequently looked at the peanut when told to click the "piña" in Spanish. And this effect was robustly significant when compared to the control condition.

Experiment 3

In Experiment 3, monolingual English bilinguals were tested in English, with the same pictures of objects as in Experiment 1, to rule out the possibility that the interlingual distractor objects might have some intrinsic visual attractiveness that is greater than that of the control objects. Objects that were labeled as interlingual competitors in Experiments 1 are only linguistically competitive if the listener knows their names in Spanish. Since these monolingual English speakers do not speak Spanish, their eyes should not be drawn to the between-language competitor distractor objects any more than to the control distractor objects.

Methods

Participants. Ten undergraduate students from the University of California, Merced participated in this study in exchange for participation credit for a course requirement. The ten student participants were monolingual English speakers. The Language Experience and Proficiency Questionnaire (Marian, Blumenfeld, & Kaushanskaya, 2007) was administered to all participants to obtain language history information in order to ensure participants spoke only English.

Apparatus. Eye movements were recorded using an Eyelink II head-mounted eyetracker. The eyetracker has three cameras mounted on the headband. Two cameras allow for the eyetracking of both eyes, while the third camera tracks the frame of the stimulus display screen, so that point of gaze can be mapped to stimuli in terms of their pixel coordinates of the computer display screen. The Eyelink II uses corneal reflection and dark pupil tracking to obtain a track of eye position with accuracy to within 0.5 degrees of visual angle.

Design. Eye movements were recorded using the same Eyelink II head-mounted eyetracker as in Experiment 1. All participants wore the headband-mounted eyetracker while they heard a spoken word in English and were asked to move a computer mouse to the corresponding picture in a visual array. The experiment consisted of two within-subjects conditions wherein each participant was exposed to a display of objects that contained the target object (referred to by name in English) and one distractor object (which was either an interlingual competitor distractor object from Experiment 1 or a neutral control distractor object from Experiment 1).

For example, one object in the display would be the target object (e.g., a bowl), the name of which was heard spoken in English over headphones. Also in the display would be the interlingual competitor object from Experiment 1, whose name in Spanish overlaps with the phonetic properties of the word "bowl" (e.g., a picture of a wedding, called "boda" in Spanish). However, since these monolingual English speakers do not speak Spanish, the name "boda" should be irrelevant to them. Neither the English name, nor the Spanish name, of the between-language competitor object was ever spoken during a participant's experimental session. For example, in the target-competitor present condition, a participant would hear the word "bowl" and would see on the right side of the computer screen a picture of a bowl and also a see a picture of a wedding on the left side of the computer screen. The target is the picture of the bowl.

In the no-competition control condition, one object would be the target object (e.g., bowl), and the other was a control object whose name had no phonetic overlap with the commonly accepted term for the target object (e.g., cake). Targets objects in this condition were the same targets used in the between-language competitor condition, but here, the targets were paired with objects that had no phonetic overlap with the target object. For example, in the no-competition control condition, a participant would hear the word "bowl" and would see on the right side of the computer screen a picture of a bowl and also a see a picture of a cake on the left side of the computer screen. The target is the picture of the bowl.

This experiment used the same filler trials as were in Experiment 1. In filler trials, a filler-trial display containing objects that were not presented in the trial types and whose names shared no phonetic similarity in either language (filler trials). In the English filler trial, for example, a filler target might be "fish" while the filler distractor object might be a kite ("huevo" in Spanish). Each participant's eye movements were recorded across 40 trials: 8 control trials: 8 between-language competitor trials, and 24 filler trials.

Procedure. Stimuli and instructions were the same as in Experiment 1. Upon arrival to the lab, participants were greeted by English-speaking research assistants. All participants were asked to fill out both a consent form and a language questionnaire. Participants were instructed to be seated in front of a computer screen, with tips of toes arranged on blue tape on the carpet, and asked to make sure both feet were firmly on the floor. After subject was seated, the eyetracker was calibrated, headphones were placed on participant's head, and participant was instructed to place hand on computer mouse. Each participant was presented with 40 trials: 8 control trials: 8 between-language competitor trials, and 24 filler trials. At the start of each trial, over headphones participant was instructed to look at the two crosshairs on the computer screen, then trial would begin. Two pictures were presented in each trial display (a target object and a distractor object). At the end of experiment, participants were asked to fill out a form that asked what they believed the experiment was testing. This was to ensure that participants were unable to recognize that some words had similarities, in which case, that participant would be removed from analyses. No participant recognized any similarities between words in experiment.

Analyses. Eye movements were sampled at 250 Hz and coded for number of looks to distractor objects (either the interlingual cohort object in the between-language competitor condition or the control object in the no-competition control condition). The proportion of eye movements to the competitor object in a between-language competitor condition was compared to the proportion of eye movements to a control object, whose name had no phonetic overlap with the commonly accepted term for the target object, in the no-competitor control condition.

Results and Discussion

A paired-samples t-test was conducted to compare the number of eye movements to the interlingual competitor distractor (between-language competitor condition) and the control distractor (no-competition control condition). As expected with these monolingual English speakers, there was no significant difference in the number of looks at the competitor distractor (M=1.00) and control distractor (M=1.02) conditions; $t(9)=0.220$, $p>.5$. Participants were just as likely to look at the between-language competitor object as a neutral control object.

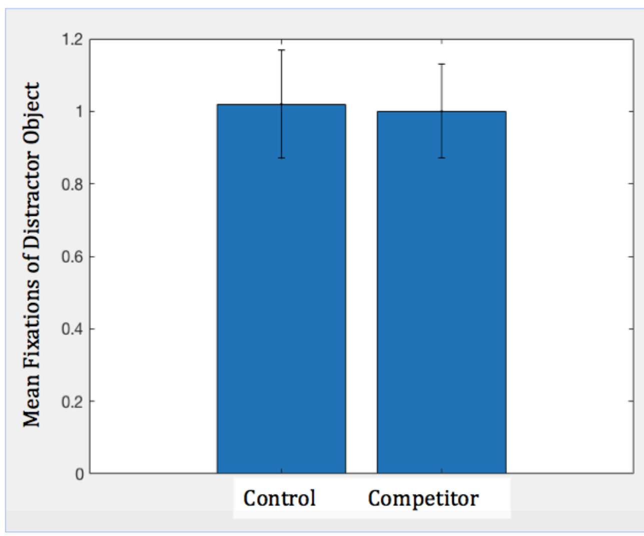

Figure 3. Monolingual English speakers did not look at the two types of distractor objects with any difference in frequency. (Error bars represent +/- 1 SE.)

The monolingual English speakers in this study, not knowing Spanish, were naturally unaffected by any between-language competition from the Spanish names of the competitor objects. Importantly, the lack of any difference in their eye movements to competitor and control objects confirms that the pictures of between-language competitor objects used in Experiments 1 and 2 do not have any intrinsic visual attractiveness that is greater than that for the control objects. Therefore, the results of Experiments 1 and 2 can safely be attributed to linguistic competition among the

Spanish and English names of those objects, and not to any distinctive visual properties of them.

General Discussion

The goal of these studies was to illustrate that how a bilingual speaker processes language is affected by the age of acquisition of the languages they speak. The results in Experiment 1, with Spanish-English bilinguals hearing English instructions, suggest that *late* bilinguals experience between-language competition, providing evidence that both languages are active during language processing. Previous research with late bilinguals has demonstrated similar results of an interlingual cohort effect (Ju & Luce, 2004, Marian & Spivey, 2003; Blumenfeld & Marian, 2007). However, in Experiment 1, *early* bilingual subjects (who had become fluent in their second language by age 7) did not exhibit between-language competition. That is, they were not looking at a "piña" when instructed to click the "peanut" in English. As expected, early-learner bilinguals did not show the interlingual cohort effect, whereas late-learner bilinguals did. In Experiment 2, a similar pattern emerged, although the interaction was not statistically significant. When we look at early bilinguals, it seems that they do not show nearly as much interlingual interference as do late bilinguals.

While previous research suggests that bilinguals may enjoy an advantage in executive control when compared to their monolingual counterparts (Bialystok, Craik, Klein, & Viswanathan, 2004), they also experience some mild deficit in real time language processing. This may be due to competition between multiple related lexical representations across the two language subsystems. Much of the data does suggest that late bilinguals experience cross-linguistic interference (Bijeljac-Babic, Biardeau, & Grainger, 1997; Duyck, Van Assche, Drieghe, & Hartsuiker, 2007). However, the present results suggest that early bilinguals may not experience those same deficits in real-time language processing. A few studies have illustrated that linguistic information may not be processed the same across all types of bilinguals, especially noting that explicit differences may exist due to age of acquisition of a bilingual speakers languages (Genesee et al., 1978; Butler & Hakuta, 2004; Fabbro, 2001; Perani et al., 2003). In a more recent study by Yow and Li (2015), adult English-Mandarin balanced bilinguals (early bilinguals) had better executive control when compared to less balanced bilinguals due to a more balanced use and level of proficiency in both of their languages. It may be the case that early-learner bilinguals' two languages may be more coordinated due to both languages being learned in tandem. As a result, early bilinguals may be more adept at switching between the two languages, compared to late bilinguals. Research has argued that bilinguals experience an advantage in executive function processes such as attentional control, cognitive inhibition, inhibitory control, working memory, and cognitive flexibility when compared to monolingual speakers (Ben Zeev, 1977; Bialystok, 1999; Prior & MacWhinney, 2010). This advantage may be more pronounced in a bilingual speaker that has learned their two languages simultaneously from language onset. For instance, neuroimaging research indicates that the areas of the brain that are activated during language processing for early bilinguals are very different from the brain areas activated in late bilinguals (Kim et al., 1997, Fabbro, 2001). When understood in the context of other research that has illustrated how linguistic and cognitive processing is not the same across all types of bilingual speakers (Genesee et al., 1978; Butler & Hakuta, 2004; Perani et al., 2003; Yow & Li, 2015), we begin to see that age of acquisition is extremely important when doing research in the bilingual domain. And we begin to see that not all bilingual speakers are the same.

Although the findings in these experiments expand our understanding of the differences that may exist between early and late bilinguals, there were limitations present in these experiments and, more than likely, present in much of the research in the bilingual domain. Due to the fact that we had to choose which group each participant would be relegated to, the studies were susceptible to selection effects, or selection bias. We selected which participants were to be placed in either early or late bilingual group, so selection was not random. Volunteer effects may have also played a role in fewer late bilinguals volunteering for participation in the experiments. Late bilinguals may have been less likely to volunteer to participate in a bilingual language study if they did not have enough confidence in their second language to participate in this experiment.

The implications of this research are far reaching. Not only does this research demonstrate that learning more than one language very early in life could improve the processing of words and possibly strengthen control of attention, but it also provides further evidence that the way we see language-learning needs to change. This is especially important when looking at second language education in schools. Research on how bilinguals process language may help to develop curriculum better suited to bilingual speakers, may also help to better detect cognitive impairments in bilinguals, and also change the time point as to when children should begin learning a second language in school.

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Appendix A: Stimuli Lists

Experiments 1 and 3: English Targets and Distractors (along with their Spanish names)

Target	Interlingual Distractor	Control Distractor
Bowl	Wedding/**Boda**	Cake/Pastel
Tornado	Sandwich/**Torta**	Piano/Piano
Peacock	Battery/**Pila**	Ladybug/Mariquita
Pliers	Beach/**Playa**	Tornado/Tornado
Web	Egg/**Huevo**	Lion/León
Popcorn	Potato/**Papa**	Carrot/Zanahoria
Boot	Mailbox/**Buzón**	Stapler/Engrapadora
Leaf	Book/**Libro**	Pie/Tarta
Peanut	Pineapple/**Piña**	Heart/Corazón
Parrot	Dog/**Perro**	Flower/Flor
Compass	Bed/**Cama**	Key/Llave
Boat	Bottle/**Botella**	Butterfly/Mariposa
Comb	Food/**Comida**	Pumpkin/Calabaza
Mice	Corn/**Maiz**	Pizza/Pizza
Gorilla	Cap/**Gorra**	Glasses/Lentes
Comicstrip	Bus/**Camión**	Grapes/Uvas

Appendix B

Experiment 2: Spanish Targets and Distractors (along with their Spanish names)

Target	Interlingual Distractor	Control Distractor
Piña/Pineapple	**Peanut**/Cacahuete	Car/Coche
Perro/Dog	**Parrot**/Loro	Cards/Tarjetas
Cama/Bed	**Compass**/Brújula	Cow/Vaca
Botella/Bottle	**Boat**/Barco	Chair/Silla
Comida/Food	**Comb**/Peine	Cockroaches/Cucarachas
Maiz/Corn	**Mice**/Ratones	Purse/Bolso
Gorra/Cap	**Gorilla**/Gorila	Cookie/Galleta
Camión/Bus	**Comicstrip**/Tira Cómica	Watermelon/Sandía
Boda/Wedding	**Bowl**/Cuenco	Apple/Manzana
Torta/Sandwich	**Tornado**/Tornado	Bear/Oso
Pila/Battery	**Peacock**/Pavo Real	Banana/Plátano
Playa/Beach	**Pliers**/Alicates	Hamburger/Hamburguesa
Huevo/Egg	**Web**/Telaraña	Beer/Cerveza
Papa/Potato	**Popcorn**/Palomitas de Maiz	Bee/Abeja
Buzón/Mailbox	**Boot**/Bota	Bread/Pan
Libro/Book	**Leaf**/Hoja	Butter/Mantequilla