Journal of Cognitive Psychology
Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/pecp21

Better early or late? Examining the influence of age of exposure and language proficiency on executive function in early and late bilinguals

Vrinda Kalia[a], Makeba Parramore Wilbourn[b] & Kathleen Ghio[b]

[a] Department of Psychology, Miami University, 90 North Patterson Avenue, Oxford, OH 45056, USA

[b] Department of Psychology & Neuroscience, Duke University, 417 Chapel Drive, 214 Soc-Psych Bldg, Durham, NC 27708, USA

Published online: 22 Sep 2014.

Journal of Cognitive Psychology, 2014
http://dx.doi.org/10.1080/20445911.2014.956748

Better early or late? Examining the influence of age of exposure and language proficiency on executive function in early and late bilinguals

Vrinda Kalia[1], Makeba Parramore Wilbourn[2], and Kathleen Ghio[2]

[1]Department of Psychology, Miami University, 90 North Patterson Avenue, Oxford, OH 45056, USA
[2]Department of Psychology & Neuroscience, Duke University, 417 Chapel Drive, 214 Soc-Psych Bldg, Durham, NC 27708, USA

Previous research has shown that early and late bilinguals differ in their language learning experiences and linguistic outcomes. However, evidence of differences between these bilinguals on measures of executive function (EF) has been mixed. As a result, the current study sought to (1) determine whether early and late bilinguals vary from one another and (2) exhibit cognitive advantages in EF relative to monolinguals. One hundred and five participants (42 monolinguals, 40 early bilinguals and 23 late bilinguals) completed the study. Participants' EF skills were assessed using the Auditorily Cued Number Numeral Task. Overall, the results did not reveal clear advantages for the early bilinguals compared to the two other groups. In fact, early bilinguals and monolinguals were equivalent in their performance on the EF task, whereas the late bilinguals were less accurate, relative to the other two groups. The differences in the performance of early and late bilinguals are discussed in terms of the *competition model* of second-language learning proposed in previous research. Taken together, these findings indicate that individual differences in EF influence the observed differences found in EF across language groups.

Keywords: Early bilinguals; Executive function; Language development; Late bilinguals.

Executive function (EF) is an umbrella term that refers to the cognitive processes involved in goal-directed behaviour (Müller, Zelazo, Lurye, & Liebermann, 2008). Although researchers disagree on the specific cognitive processes considered fundamental components of EF, three cognitive skills have received the most empirical attention: inhibition, updating, and shifting (Miyake & Friedman, 2012). Several researchers have argued that individuals' abilities to (1) inhibit a dominant or prepotent response (i.e. inhibition), (2) actively monitor incoming information for its task relevance (i.e. updating), and (3) shift attention back and forth between tasks (i.e. set shifting) are essential aspects for the development of EF (Anderson, 2002). However, the degree to which the development of these skills influence *or* are influenced by other emerging skills remains hotly debated (Miyake & Friedman, 2012). Some scholars have speculated that the cognitive abilities that underlie EF are mediated by language (Jacques & Zelazo, 2001).

Correspondence should be addressed to Vrinda Kalia, Department of Psychology, Miami University, 90 North Patterson Avenue, Oxford, OH 45056, USA. E-mail: kaliav@miamioh.edu

We would like to sincerely thank Vidhya Raju, Laura Kurtz and Carla Wall for their assistance in stimuli creation, data collection, coding and data entry. We would also like to thank the Ashley Ruba and the WILD writing group for all of their helpful suggestions on previous drafts of the manuscript. Finally, we would like to express our sincerest gratitude to all of the participants who participated in the study.

For instance, Jacques and Zelazo (2001) contend that in order for individuals to recruit the cognitive processes required for goal-directed action, they use language to regulate their thoughts and behaviour. Zelazo (2006) proposes that this reliance on language begins in childhood when a child uses internal or self-directed speech to formulate rules (e.g. "If I use the bathroom, then I get to pick a sticker") about their behaviour. As a result, Marcovitch and Zelazo (2009) have argued that children's developing language abilities are a driving force in the development of EF. But what is the relationship between language and EF in individuals who are learning two languages?

In an exciting proposal, Bialystok (2001) suggested that the demands of managing two languages, over time, afforded bilinguals cognitive benefits that generalised beyond the linguistic domain. This proposal is based largely on Green's (1998) *inhibitory control model.* Since bilinguals' dual languages are activated simultaneously (Blumenfeld & Marian, 2013), when they use either language it requires them to suppress the language not relevant to the task at hand. According to Green, suppression of the irrelevant language is accomplished with the help of an inhibitory control mechanism. One of the assumptions of the inhibitory control model is that bilinguals have a supervisory attentional system that reacts to activation of the irrelevant language. The more strongly the irrelevant language is activated, the greater the inhibition generated by the bilingual's attention system (Green, 1998).

Based on Green's (1998) model of inhibitory control, Bialystok (2009) proposed that continuous use of two languages affords bilinguals particular cognitive advantages associated with the development of EF. For instance, in order to suppress or inhibit the competing language system, bilinguals must exert attention control and appropriately allocate cognitive resources. As a result, Bialystok (2001) contends that bilinguals experience cognitive advantages in inhibition because they must continually work to suppress their irrelevant language. Over the last few decades, some evidence has supported the claim that sustained dual-language experience affords bilinguals with particular benefits in inhibition (e.g. Bialystok & Martin, 2004) as well as additional cognitive processes associated with EF (Bialystok & Craik, 2010; Craik & Bilaystok, 2006). More specifically, some have also argued that continual engagement in these complex cognitive processes enhances bilinguals' attention control (e.g. Costa, Hernández, & Sebastián-Gallés, 2008) and conflict resolution (e.g. Bialystok, Craik, Klein, & Viswanathan, 2004) skills.

More recently, however, notable studies have not found reliable differences between bilinguals and monolinguals (e.g. Morton & Harper, 2007). In their recent review, Hilchey and Klein (2011) raised concerns about the failures of these studies to detect the bilingual advantage in inhibitory control in both children and young adults. Hilchey and Klein (2011) summarised that the "absence of a bilingual advantage in these age groups is simply inconsistent with the proposal that bilingualism has a general positive effect on inhibitory control processes" (p. 629).

The cautionary tone of Hilchey and Klein (2011) has resonated in a spate of studies demonstrating equivalent performance of bilinguals and monolinguals in non-linguistic executive control tasks, both with adults (e.g. Kousaie & Phillips, 2012; Paap & Greenberg, 2013) and children (e.g. Duñabeitia, Hernández, Antón, Macizo, Estévez, Fuentes, & Carreiras, 2014; Morton & Harper, 2007). Hilchey and Klein (2011) concede that bilinguals do appear to enjoy some general processing advantages and that a lifetime exposure to two languages ultimately influences their neural organisation (Abutalebi, 2008). The degree to which the duration of dual-language exposure (e.g. lifetime bilingualism) alone drives advantages in EF remains uncertain (Paap & Greenberg, 2013). However, one way to unpack the effect of dual-language exposure on EF would be to contrast bilinguals who have had more exposure to both languages (i.e. early bilinguals) to bilinguals who have had less exposure (i.e. late bilinguals).

EARLY VERSUS LATE BILINGUALS

Most research examining bilinguals has compared monolinguals to early bilinguals, who (1) became bilingual very early (i.e. before age 5) in life and (2) are equally proficient in both their languages. Although learning a second language later in development can be particularly challenging (Linck, Kroll, & Sunderman, 2009), research has largely overlooked the cognitive implications of becoming bilingual later in development (i.e. late bilinguals). Late bilinguals, for example, may not only differ from early bilinguals in terms of proficiency in both of their languages (e.g. Luk, De Sa, & Bialystok, 2011) but also differ in neural organisation (e.g. Hernandez, Hoffman, & Kotz, 2007; Hull & Vaid, 2007; Kim, Relkin, Lee, & Hirsch 1997).

Recent neuroimaging studies have shown that bilinguals who acquired their languages either early (i.e. before age 5) or late (i.e. after age 10) differed significantly in grey matter density (Mechelli et al., 2004). More specifically, Mechelli et al. (2004) found that early bilinguals had greater densities of grey matter in the inferior parietal area of the left and right hemispheres relative to late bilinguals. This research also revealed that bilinguals' proficiency in their second language was negatively correlated with the age at which they acquired it, yet positively correlated with their grey matter density. Thus, late bilinguals were more likely to (1) have less grey matter than early bilinguals and (2) be less proficient in their second language. Although the prevailing notion is that *both* the quality and timing of dual-language exposure play important role in the different outcomes for bilinguals, important questions remain as to which *specific* factors account for the observed differences in neurocognition and language development between early and late bilinguals.

LANGUAGE DEVELOPMENT: EARLY VERSUS LATE BILINGUALS

Two different theories have been proposed to account for why and how the timing of second-language exposure impacts bilinguals' language development. The *critical period hypothesis* (Johnson & Newport, 1989) highlights the *outcome* of learning a second language (e.g. proficiency). According to this hypothesis, differential outcomes for early and late bilinguals occur because late bilinguals do not acquire native-like proficiency levels in their second language and as a result, language competence does not increase at a steady rate. Since language competence peaks at a particular age, typically early in development, and gradually declines thereafter, learning a second language later in development is less advantageous. Support for this perspective is provided by behavioural studies, demonstrating that older ages of second-language acquisition are associated with lower levels of proficiency (e.g. DeKeyser, 2000).

In contrast to this critical period hypothesis, the *competition and entrenchment model* of Hernandez, Li, and MacWhinney (2005) emphasises the *process* of learning a second language, as opposed to the outcome. According to this perspective, developmental processes that underlie second-language acquisition are what lead to the differences between early and late bilinguals. Hernandez et al. (2005) contend that the factors that contribute to the differences in these developmental processes are (1) brain plasticity and (2) first-language entrenchment. For instance, early in development, children's exposure to their language is represented neurologically as sounds. Early bilinguals, exposed to two languages from infancy, spend a considerable amount of time during preverbal development processing speech streams from two different languages. By the time early bilinguals begin producing language, this early bilingual exposure facilitates their ability to keep both languages separate (Hernandez et al., 2005).

The late bilingual, on the other hand, acquires their second language *after* their first language has already created an intricate lexical (sound), syntactic (rules of use) and semantic (word meanings) neural network. As this network becomes more ingrained, the late bilingual's first language (hereafter, L1) becomes easier and more automatic in use. In effect, for late bilinguals, their L1 has already become entrenched by the time they are exposed to their second language (hereafter, L2). As a result, the L2 then competes or is parasitically related to the L1. For example, in order to use the word, "manzana," the late bilingual initially must think of the word, "apple" (Hernandez et al., 2005). Thus, words from the L2 will cluster closely with relevant representational (e.g. symbol) and phonological (e.g. sound) information from the L1. In essence, the late bilingual learns the L2 *in relation to* their L1 (Hernandez et al., 2005).

In addition to the entrenchment of L1, late bilinguals also acquire their L2 with reduced neuroplasticity. Therefore, in order to achieve a *separate* network for each language, late bilinguals must recruit other cognitive skills or use various strategies to help reduce the parasitic dependence of their L2 on their L1. Reducing this dependence can be done through increased exposure to L2 and through metacognitive strategies, like rehearsal, imagery, and recoding (Hernandez et al., 2005). Ultimately, this increased exposure and strategy use is thought to enhance a proficient late bilingual's ability to think of "manzana," independent of the word, "apple."

Thus, several factors likely influence late bilinguals' ability to create this independent L2 network, such as (1) how deeply entrenched L1 is, (2) available plasticity and (3) the dedicated and effective use of metacognitive strategies like rehearsal and imagery. As a result, clear differences should exist between bilinguals who learned their L2s earlier in development rather than later because of L1 entrenchment and brain plasticity.

Yet, it is not just brain plasticity that influences L2 development. Differences should also be evident between late bilinguals who are more or less proficient in their second language because of their use of these metacognitive strategies and increased L2 exposure. Based on the model of Hernandez et al. (2005), late bilinguals who are not balanced in their two languages should differ from late bilinguals who have achieved equal proficiency. Late bilinguals who are more proficient in both their languages may *also* have improved metacognitive strategies. As a result, this model would also predict that late bilinguals experience greater L1 interference when learning their L2 than early bilinguals. Thus, late bilinguals who become more proficient in both languages are also more likely to have resolved the interference from L1 through increased L2 exposure and/or through the use of metacognitive strategies. Alternatively, late bilinguals who are less proficient in both languages likely experience greater interference from the non-target language. Thus, it is plausible that late bilinguals who demonstrate balanced proficiency in L1 and L2 also exhibit enhanced EF skills.

EF: EARLY VERSUS LATE BILINGUALS

Although language development theories suggest that early and late bilinguals differ in language-related processes, it is essential to determine *how* early and late bilingualism impacts EF. Some studies have shown that late bilinguals, when compared to early bilinguals, experience additional processing demands when using language, as evidenced by increased activity in the cortical region of the brain (Hernandez et al., 2007). Recent behavioural research has provided contradictory results on EF in early and late bilinguals. For instance, Pelham and Abrams (2014) compared late and early bilinguals to English monolinguals. Their early bilinguals spoke Spanish as their L1 (English = L2), whereas their late bilinguals spoke English as L1 (Spanish = L2). Bilinguals' EF skills were assessed using the attention network task, which measures participants' ability to suppress interference from distracters. Participants' performance was evaluated in terms of accuracy and reaction time (RT). The findings revealed that both groups performed better than the monolinguals on the task. However, the early and late bilinguals generated similar accuracy scores and did not significantly differ in RT on the incongruent or conflict trials.

In contrast, Luk et al. (2011) compared a group of early and late bilinguals to English monolinguals, on the Flanker task, which examines inhibitory control processes. Participants' RTs were analysed and revealed significant differences on the following: (1) RT differences between incongruent (conflict) and control trials and (2) RT differences between congruent and incongruent trials. The RT differences, for incongruent versus control and incongruent versus congruent, indicate that the early bilinguals experienced less costs relative to the late bilinguals. This was seen as a marker for their greater inhibitory control capacities relative to the late bilingual and English monolingual participants. Furthermore, the late bilinguals performed equivalently to the monolinguals.

Although both the studies mentioned earlier provide valuable insights (Luk et al., 2011; Pelham & Abrams, 2014), it is important to note that both studies used different strategies to classify early and late bilinguals. For example, Pelham and Abrams (2014) used the age that their bilinguals reported becoming *fluent* in their L2. Whether a participant was "fluent" in their L2 was determined by their ability to carry on a conversation with a Spanish-speaking experimenter. Participants who reported becoming fluent by the age of 7 were classified as "early," whereas participants who reported becoming fluent at or after age 13 were classified as "late." Luk et al. (2011), on the other hand, asked bilinguals to report the age at which they became *actively* bilingual (i.e. use both languages). Participants who reported being actively bilingual at or before age 10 were classified as "early," whereas participants who reported being actively bilingual after age 10 were classified "late." In both these experiments, participants who did not meet the criteria set by the experimenters for early or late were dropped from the study. In addition, in both studies, early and late bilinguals differed in language proficiency.

In our view, this creates several confounds when interpreting the previous findings. First, the early and late classification schemes used in these studies included the *combined* effect of age and duration of L2 exposure. However, according to Hernandez et al. (2005), *both* L2 exposure and available brain plasticity influence the L2 acquisition. Thus, it is difficult to determine which factors were more or less influential in the previous studies. It is highly likely that an early bilingual who learned his or her L2 at age 7 experienced significantly more interference (i.e. more L1 entrenchment) and possessed less neuroplasticity relative to an early bilingual, who learned his or her L2 at age 2.

In addition to differences in entrenchment and neuroplasticity, the early and late bilinguals in both studies differed in their L2 proficiency. Late bilinguals had significantly lower levels of language proficiency than the early bilinguals (Luk et al., 2011; Pelham & Abrams, 2014). The *competition and entrenchment model* also predicts that with "dedicated" use of metacognitive strategies, late bilinguals may achieve proficiency levels comparable to those of early bilinguals. Since, neither study controlled for language proficiency in their analyses, the degree to which differences between early and late bilinguals were *specifically* influenced by L2 proficiency remains unknown.

Thus, the purpose of the current study was to pinpoint the differential effects of age of L2 exposure *and* language proficiency on EF. To accomplish this goal, the current study compared three language groups: early bilinguals, late bilinguals and monolinguals. Participants' EF skills were assessed using the auditorily cued number-numeral task (ACNNT; Zelazo, Craik, & Booth, 2004). The ACNNT was developed by Zelazo et al. (2004) as a deductive rule-use sorting task that could be used effectively with a wide range of ages and cognitive capacities. Since it was highly possible that the three language groups would have different levels of EF skills, we chose a task that was sensitive enough to expose any variability that might exist across the language groups. A fundamental assumption of this task is that individuals across ages differ in the maximum number of hierarchically complex rules (i.e. "if–then" propositions) they can process at any one time. Young adults, for instance, may be able to construct increasingly complex rules, but may experience difficulty holding these rules in their working memory and responding to them appropriately on the fly (Zelazo et al., 2004). As a consequence, participants would have to expend a fair amount of attentional resources to complete the task. This expenditure would then influence their accuracy, perseverative errors and RTs on the task.

Based on the *competition model* (Hernandez et al., 2005), which predicts greater interference for the late bilinguals, and previous work by Pelham and Abrams (2014), who found that early and late bilinguals performed equivalently on EF, we predicted the following: (1) If, the early and late bilinguals, in our sample, were equally proficient in their two languages, then the late bilinguals would exhibit benefits in EF relative to the early bilinguals and monolinguals. Moreover, if as predicted by Hernandez et al., the "dedicated" use of strategies assists bilinguals in overcoming or minimising L1 interference, then late bilinguals who are less proficient in both languages may also be less efficient in the use of metacognitive strategies. In such circumstances, it would be imprudent to predict differences between early and late bilinguals. Thus, either the late bilinguals should perform worse than early bilinguals and monolinguals on the task or perform at equivalent levels relative to the other two groups.

METHODS

Participants

One hundred and five college-aged (18–22 years; M_{age} = 19.7 years, SD_{age} = 1.06 years) adults (males = 44) participated in the study. Participants were recruited from an undergraduate psychology research pool at a highly selective (i.e. 29% acceptance rate) private, southeastern university. The average range of SAT scores of accepted students at this school at the time of the study was as follows: Math = 690–790, Verbal/Critical = 680–780 and Writing = 690–790. Of the 105 participants, 42 were monolinguals and 63 were self-reported bilinguals. Participants received either class credit or $12 in compensation for participation.

It is important to highlight that this convenience sample of bilinguals was not actively and selectively recruited based on the age they were first exposed to their L2. All participants completed a language history questionnaire that assessed their age of L2 acquisition, language history and proficiency, in addition to demographic information (see Table 1). Thus, bilingual participants were classified as either "early" or "late" based on the information they provided at the time of testing. Based on previous research (e.g. Hull & Vaid, 2007; Perani et al., 2003), bilinguals were classified as "early" if they had acquired their L2 *prior to* age 6 and classified as "late" if they acquired their L2 *at and after* age 6.

TABLE 1
Means and standard deviations for background and oral language measures by language group

Language group	n	*Age*	*Age of English exposure*[a]	*Age of other language exposure*	*Years of English exposure*	*Years of other language exposure*	*Other language proficiency*[b]	*PPVT*	*EVT*	*CTOPP*
Early	40	19.82 (1.45)	3.27 (3.51)	1.92 (1.96)	16.60 (3.74)	18.81 (1.62)	5.76 (1.28)	110.33 (11.35)	112.33 (14.06)	104.15 (12.90)
Late	23	19.72 (.76)	3.26 (3.92)	9.65 (3.08)	16.37 (3.77)	13.24 (4.85)	5.23 (1.09)	109.70 (10.88)	117.22 (13.88)	100.00 (15.14)
Monolingual	42	19.55 (1.16)		–		–	–	110.50 (8.41)	116.21 (12.65)	101.57 (14.35)

[a]English was the second language for 30 bilinguals (24 = Early, 6 = Late Bilinguals).
[b]Based on a 7-point scale (7 indicating native proficiency).
Other language = Not English. Twelve bilinguals (8 = Early, 4 = Late) reported English was not their dominant language, and analyses conducted without these participants did not alter findings.

All the monolingual participants reported that their nationality was American. Of the 63 bilinguals, 28 reported that their nationality was not American. Reported nationalities included Korean (n = 5), Chinese (n = 5), Brazilian (n = 2), Singaporean (n = 2), Colombian (n = 3) and one each of Russian, Nigerian, Latvian, Swedish, Haitian, Finish, Sri Lankan, Croatian, Costa Rican, Mexican and Guatemalan. In addition to English, bilinguals reported consistently speaking: Spanish, French, Portuguese, Russian, German, Italian, Finnish, Swedish, Hebrew, Korean, Chinese, Amharic, Igbo, Sinhala and Haitian-Creole. Twenty-six bilinguals (7 = Late Bilinguals) reported speaking a third language. Twenty bilinguals (5 = Early Bilinguals) reported learning their L2 in school and 42 (7 = Late Bilinguals) reported being exposed to their L2 at home. Preliminary analyses showed no differences in either oral language skills or EF measures for the home-exposed versus school-exposed bilinguals, F values ranged from .95 to .00, all p values > .10. Although we were unable to account for differences in terms of socioeconomic status, since the participants were from such diverse cultural and linguistic backgrounds, we made the decision to match them intellectually, albeit crudely, using a measure of receptive English vocabulary (discussed in detail later in the text).

Materials and procedure

Participants were assessed individually, in testing sessions lasting approximately 1 hr. The following tasks were administered:

Proxy for general intelligence. As an assessment of participants' general intelligence, we administered the Peabody Picture Vocabulary Test—4th Edition (PPVT-4). Similar to Beaujean and Osterlind (2008), we used participants' scores on the PPVT-4 (Dunn & Dunn, 2007) as a proxy for general intelligence because previous research has confirmed that a strong and positive relationship exists between individuals' performance on the PPVT and intelligence quotient (IQ) assessments (Bell, Lassiter, Matthews, & Hutchinson, 2001; Dunn & Dunn, 1981, 1997; Watson & Severson, 1976; but see also Altepeter & Johnson, 1989). It is important to emphasise that we did not view the PPVT as an IQ test, per se. However, after careful consideration, we chose to use the PPVT as a reliable, albeit less than ideal, proxy for intellectual skills for two reasons. First, we were not using it as a screening instrument with clinical populations or adults with intellectual disabilities (Altepeter & Johnson, 1989; Maxwell & Wise, 1984) and second, Bell et al. (2001) found that the PPVT served as a reliable indicator of performance on the Wechsler Adult Intelligence Scale with average to high-average intelligence; a population similar to the current study's population.

The PPVT-4 assesses individuals' receptive vocabulary in Standard American English (Dunn & Dunn, 2007). In this task, participants are shown four pictures on a page. Each picture is numbered. Participants are required to either point to the corresponding picture or say the number assigned to matching picture after the experimenter states the corresponding label or word (e.g. "bike"). The pictures depict objects, actions or concepts, and items are arranged in sets of 12. The task progresses with increasing difficulty. A ceiling is established when the participants make 8 errors out of a block of 12 trials. Raw scores are converted to standard scores on the basis of the participant's age, with a mean of 100 and a standard deviation of 15.

English oral language assessments. Participants' English oral language skills were assessed using the following tasks:

1. Expressive Vocabulary Test—2nd Edition (Williams, 2007): The Expressive Vocabulary Test-2 (EVT-2) is an individually administered, norm-referenced test of expressive vocabulary and word retrieval in English for individuals between the ages of 2.6 and 90+ years (Williams, 2007). In this task, participants are shown a picture (e.g. stone) and must provide either a one-word label (e.g. "stone") or synonym (e.g. "rock") for the object, action, adjective, etc. depicted in a given image. A ceiling is established when the participant has five consecutive incorrect responses. Raw scores were used to derive a standard score based on the participant's age, with a mean of 100 and a standard deviation of 15.
2. Comprehensive Test of Phonological Processing—CTOPP (Wagner, Torgesen, & Rashotte, 1999): Since research has provided compelling evidence that phonological awareness skills are (1) predictive of language learning outcomes in adults (e.g. Kaushanskya & Marian, 2007) and (2) related to working memory processes (e.g. Gathercole & Baddeley, 1990), we assessed participants' phonological awareness skills using the CTOPP. The CTOPP is an administered-individually, norm-referenced test of reading-related phonological awareness skills for individuals between the ages of 4 and 24.11 years (Wagner et al., 1999). The Blending and Elision subtests were administered for all adult participants. Blending involves identifying a word from the sound of its parts. For example, participants are asked to carefully listen to the examiner and combine sounds to create another word (e.g. "what word do these sounds make? /t/ /æ/ /n/ = *tan*). Elision involves deleting a sound from a word to create a new one (e.g. "say *spider*, without the */der/*" = *spy*). Responses were scored as either correct or incorrect, with a ceiling established with three consecutive incorrect items. Raw scores for the two subtests were added and the final score was used to derive a standard score on phonological awareness based on the participant's age, with a mean of 100 and a standard deviation of 15.

Executive function assessment. Participants' EF skills were assessed using ACNNT, created by Zelazo et al. (2004). The ACNNT requires participants to hold stimulus–response rules in working memory and suppress a preponderant response, which broadly assesses conflict resolution and inhibitory control (Zelazo et al., 2004). It was administered on a touchscreen computer monitor displaying a 2 × 2 grid (see Figure 1). Each quadrant contained black squares and an Arabic numeral. The number of squares did not correspond to the numerals in that quadrant. Forty trials were presented in the male voice, and 10 trials were presented in the female voice. If the number spoken was in the male voice (majority), participants touched the quadrant corresponding to the number of squares. If the number spoken was in a female voice (minority), participants touched the quadrant corresponding to the numeral. The presentation of the female voice trials and the numbers were distributed randomly. Since this task assesses sustained attention and cognitive inhibition, the preponderance of male voice trials was intended to induce sorting by a particular dimension and then inhibit this salient response at random intervals. Participants' performances were evaluated in terms of accuracy, inhibition and cognitive costs:

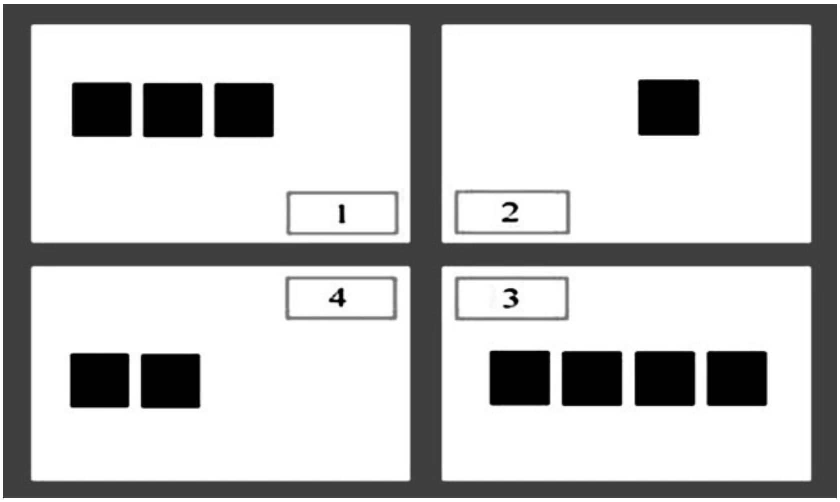

Figure 1. Auditorily cued number numeral task (ACNNT).

- Accuracy: evaluated by the number of correct responses made divided by the total number of trials (hereafter, Proportion Correct).
- Inhibition (Perseverative errors): to inhibit the previous task or a prepotent response—Adjusted Proportion of Perseverative Errors (Adjusted PPE). This was calculated by the following formula: Adjusted PPE = Pr(Perseverative Errors) – .5 Pr(Non-perseverative Errors). A perseverative error was counted if it was the correct response according to the *other* rule (e.g. number of squares versus the numeral); otherwise, it was considered non-perseverative (Zelazo et al., 2004).
- Switching costs: Since bilinguals routinely switch between their two languages, researchers have speculated that they may also experience an advantage in switching between tasks (Prior & MacWhinney, 2010). When individuals switch between tasks, they are required to activate the currently relevant stimulus–response association as well as configure the stimulus–response association to the new task (Hernández, Martin, Barceló, & Costa, 2013). In order to accomplish this complex cognitive activity, additional processing resources are needed, resulting in slower RTs during the new task. In the ACNNT, participants' ability to switch between tasks (or rules) is most evident during the minority (female voice) trials. In order to successfully switch tasks, participants must keep in mind the sorting rule for the majority (male voice) trials and reconfigure their responses for the minority (female voice) trials. As a result, switching costs RTs were calculated by subtracting the average RT for majority trials *before* a minority trial from the average RT for minority trials. Participants should generate faster RTs during the majority trials immediately before the minority trials and the cost of switching from majority to minority trials should result in slower RTs for the minority trials.

RESULTS

Descriptive statistics for participants' oral language and EF scores are presented in Tables 1 and 2, respectively. For all analyses, the alpha level was set at .05 and automatic corrections were

TABLE 2
Means and standard deviations for the measures of EFs by language group

Language group	n	*Proportion correct*	*Adjusted PPE*	*Switching costs (in milliseconds)*
Early	40	.99 (.01)	.32 (.60)	415.30 (2077.14)
Late	23	.96 (.07)	.55 (1.34)	77.50 (475.87)
Monolingual	42	.99 (.01)	.44 (.71)	–198.03 (1868.25)

used for unequal sample sizes across groups (Neter, Kutner, Wasserman, & Nachtsheim, 1996). Preliminary analyses failed to yield significant differences between males and females on any of the dependent measures, all p values > .10. Thus, subsequent analyses were collapsed across gender.

In addition, bilingual participants' ratings of their proficiency in speaking and understanding their other language (i.e. not English) was calculated and averaged to create the other-language proficiency variable (see Table 1). These ratings were subjected to a between-subjects one-way analysis of variance (ANOVA), with Bilingual Group (Early vs. Late) administered as the independent variable. The analysis confirmed that early and late bilinguals did not significantly differ in their self-reported proficiency in their other language, F (1, 62) = 1.84, $p > .10$.

English language measures

To explore potential differences in English language skills between the groups, participants' performances on the oral language measures (i.e. PPVT, EVT and CTOPP) were subjected to a one-way multivariate ANOVA, with Language Group (Monolingual vs. Early Bilingual vs. Late Bilingual) administered as a between-subjects variable. The analysis did not yield a significant overall main effect of Language Group, F (2, 102) = 1.73, $p > .10$, Wilk's $\Lambda = 0.90$, $\eta_p^2 = .05$. No significant differences between the language groups emerged on any individual oral language measures, F values ranged from 1.25 to .05, and all p values were >.10. Therefore, the language groups generated similar scores across all the English language measures.

Executive function measure

In line with previous research (e.g. Bell et al., 2001; Beaujean & Osterlind, 2008), we used the participants' PPVT scores as proxies of their general intellect. As such, we controlled for (i.e. covaried) participants' PPVT scores for all EF analyses.[1]

Accuracy and inhibition. Participants' proportion correct and their adjusted proportion of perservative errors (Adjusted PPE) on the ACNNT were subjected to a one-way multivariate analysis of covariance with Language Group administered as the between-subjects variable and PPVT scores as the covariate. A significant overall main effect of Language Group emerged, F (2, 102) = 2.71, $p < .05$; Wilk's $\Lambda = 0.89$, $\eta_p^2 = .05$. Univariate analyses yielded a significant main effect of Language Group on Proportion Correct F (2, 102) = 5.40, $p = .006$, $\eta_p^2 = .10$, but not on Adjusted PPE, F (2, 102) = .50, $p < .10$. Bonferroni comparisons revealed that the Late Bilinguals were significantly less accurate (i.e. lower proportion correct) relative to the Early Bilinguals, F (2, 102) = 3.06, $p < .01$, $\eta_p^2 = .09$, 95% confidence interval (CI) [.01, .04]. We assessed the relative evidence for an effect versus a null effect using the JZS Bayes factor as described by Rouder, Speckman, Sun, Morey, and Iverson (2009). The prior effect-size scale was .7, a reasonable value in this context. The resulting Bayes factor is .08 in favour of the alternative, indicating that the alternative hypothesis was 11.52 times more likely than the null. The Late Bilinguals were also less accurate than the Monolinguals, F (2, 102) = 2.92, $p = .00$, $\eta_p^2 = .08$, 95% CI [.00, .04]. Again, we assessed the relative evidence for an effect versus a null effect using the JZS Bayes factor as described by Rouder et al. (2009). The prior effect-size scale was .7, a reasonable value in this context. The resulting Bayes factor is .11 in favour of the alternative, indicating that the alternative hypothesis was 8.40 times more likely than the null. However, Early Bilinguals' were as equally accurate as the Monolinguals, $p = .84$, 95% CI [−.01, .01]. Significant differences did not emerge between the groups for Adjusted PPE, with all p values > .10 (see Figure 2).

Switching costs. Participants' switching costs (mean RT for male trials prior to female trials – mean RT for female trials) in milliseconds were subjected to a one-way analysis of covariance. The analysis did not yield a significant main effect of Language Group, F (2, 100) = .67, $p > .10$, indicating that the ability to shift between trials and tasks did not vary across the three language groups.

Correlations. The degree to which participants' oral language skills and EF were associated was investigated by conducting partial correlation analyses, controlling for PPVT. Prior to running these analyses, the data were checked for assumptions of normality. The proportion correct on the EF task was slightly negatively skewed; however, arcsine transformations effectively resolved the

[1]Analyses conducted without PPVT as a covariate did not change the findings.

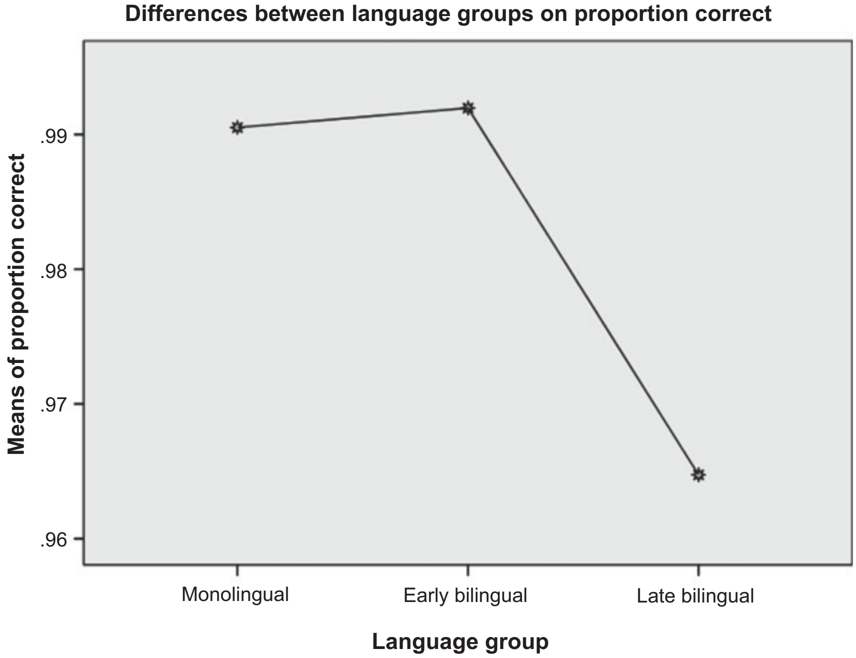

Figure 2. Differences between language groups on accuracy, with PPVT as covariate in the model.

problem (Neter et al., 1996). Similarly, participants' Switching Costs and Adjusted PPE were moderately skewed; however, $\log_{10}$ transformations failed to distribute the Adjusted PPE and Switching Costs data normally. Since Adjusted PPE was strongly correlated to proportion correct ($r = -.52$, $p = .000$) and no differences had been observed for Switching Costs, these variables were dropped from subsequent analyses. Also, the sample size for the Late Bilinguals was small ($n = 23$), so partial correlations for this group can only be considered exploratory. These data are depicted in Table 3. The findings revealed that for the Late Bilinguals, scores on the expressive vocabulary measure (i.e. EVT) were negatively correlated with other-language proficiency, demonstrating that participants who had larger expressive vocabularies in English reported being less proficient in their other language. In addition, Late Bilinguals' English expressive vocabulary

TABLE 3
Partial correlations, controlling for PPVT, between English oral language and EFs

	EVT	*CTOPP*	*Proportion correct*	*Other language proficiency*
Whole sample				
EVT	–	.39**	.05	–
CTOPP		–	.03	–
Proportion correct			–	–
Early bilinguals				
EVT		.26	.12	–.16
CTOPP		–	–.05	.08
Proportion correct		–	–	.18
Late bilinguals				
EVT		.44*	.24	–.57**
CTOPP		–	.04	–.10
Proportion correct		–	–	.25

*$p < .05$, **$p < .01$.

was positively associated with their metalinguistic awareness (i.e. CTOPP scores).

DISCUSSION

The goal of the current study was to disentangle the differential effects of age of L2 exposure *and* language proficiency on EF. To accomplish this goal, three different language groups were compared: English monolinguals, early bilinguals (L2 exposure prior to age 6) and late bilinguals (L2 exposure at or after age 6). Participants' oral language skills in English (i.e. receptive and expressive vocabularies, phonological awareness) were measured and EF skills were assessed using the ACNNT (Zelazo et al., 2004), which broadly assesses conflict resolution and inhibitory control. Participants' performance on the ACNNT was analysed in terms of accuracy, inhibition and switching and monitoring effects.

Accuracy and inhibition

Participants' accuracy on the ACNNT was evaluated by calculating the proportion of correct responses on the ACNNT. The findings revealed that across the language groups, late bilinguals were significantly less accurate on the task relative to the monolingual and early bilingual participants. However, monolinguals and early bilinguals were equally accurate and performed with near-perfect accuracy. Although it is tempting to assume that the late bilinguals were hindered in their ability to inhibit irrelevant information in this minimally linguistic EF task because of the competing demands of their two languages, a few important issues must be highlighted.

First, it should be noted that, consistent with previous research (e.g. Bialystok, Craik, & Lik, 2008; Luk et al., 2011; Pelham & Abrams, 2014), participants in the current study performed at near-ceiling levels on the task (mean accuracy ranged from .96 to .99). Thus, any interpretation of such high levels of accuracy raises concerns about variability in the sample. It is possible that a few of the late bilinguals were responsible for a disproportionately large number of errors. The large standard deviations (.07 = proportion correct, 1.34 = Adjusted PPE) for the Late Bilinguals provides support for this notion. In addition, differences in perseverative errors between the groups were not evident, using the Adjusted PPE, the method recommended by Zelazo et al. (2004) for calculating inhibition effects on the ACNNT. These results are consistent with previous research that has failed to detect a bilingual advantage in inhibition (e.g. Duñabeitia et al., 2014; Paap & Greenberg, 2013).

However, the means for the three groups reveal a trend similar to the findings for proportion correct, with the late bilinguals generating the most perservative errors. Since participants' proportion correct scores were moderately and negatively correlated with perseverative errors and positively correlated with monitoring effects, it is likely that these variables share a good deal of variance. Thus, it is important to not overlook late bilinguals' lower accuracy scores on the EF task.

Switching effects

The picture is more complex when interpreting the RT data in terms of switching costs. Overall, a coherent pattern of bilingual advantage was not evident, as differences between the language groups in switching effects did not emerge. This finding is consistent with recent results reported by Hernández et al. (2013) and Paap and Greenberg (2013). Although previous studies have shown that bilinguals' ability to switch between languages, on-demand, may benefit general task-switching performance (e.g. Prior & Gollan, 2011), careful examination of switching effects in recent work has shown that this phenomenon may be hard to replicate (Hernández et al., 2013). In fact, perusal of the participants' RTs demonstrates that the (1) late bilinguals had lower switching costs than the early bilinguals and (2) monolinguals were at an advantage in relation to the bilinguals.

It is possible that we failed to find differences between the groups due to task effects. To assess EF, we used a single, minimally linguistic task that has never been used with a bilingual population. As Hilchey and Klein (2011) pointed out, differences in task difficulty and introduction of response competition influence RTs on EF tasks. However, the findings of the current study are consistent with recent research (e.g. Kousaie & Phillips, 2012; Paap & Greenberg, 2013). For instance, Paap and Greenberg (2013) found that after systematically controlling for influencing variables, like IQ, SES and language proficiency, differences were not evident between monolinguals and bilinguals in switching or monitoring costs in any of the EF tasks administered (i.e. Antisaccade, Simon and Flanker). Since very few studies have systematically studied conflict resolution via switching costs in this way, we must temper our claims until additional research has been conducted.

The current findings vary from the work of Luk et al. (2011), who found that early bilinguals performed significantly better than late bilinguals, and more recently, Pelham and Abrams (2014) who found that early bilinguals and late bilinguals performed better than monolinguals on EF. Several factors may have contributed to these contrasting results. First, both studies used age of *active use* (Luk et al., 2011) and *fluency* (Pelham & Abrams, 2014) as indicators of bilingualism, whereas we used age of L2 exposure in the current study. Second, the late bilinguals in the current study had more number of years of L2 exposure, on average, than the bilinguals in the studies by Luk et al. (2011) or Pelham and Abrams (2014). The difference in years of exposure may be due to the fact the late bilinguals in our sample were exposed to their L2 at or after age 6, as opposed to at or after age 10 (Luk et al., 2011) or 13 (Pelham & Abrams, 2014). Third, and we think *most importantly*, the early and late bilinguals in the current study did *not* significantly differ in terms of their L1 or L2 proficiencies. In the Luk et al. (2011) study, the late bilinguals had significantly lower PPVT scores than the monolinguals and early bilinguals. Similarly, in the Pelham and Abrams (2014) study, the early bilinguals reported significantly higher L1 and L2 proficiency than late bilinguals.

It is worth noting that Tao, Marzecova, Taft, Asanowicz, and Wodniecka (2011) and Linck, Hoshino, and Kroll, (2008) studied populations that differed in L1 and L2 proficiency levels; however, differences in proficiency did not appear to influence their results. Considering the dearth of studies that have compared early and late bilinguals, it is challenging to draw firm conclusions, but an inconsistent pattern in the findings underscores the need for additional research in the area.

Early versus late bilinguals

The findings of this study raise interesting questions about the development of EF in bilinguals. One important avenue of research would be to examine the developmental trajectory of EF in bilinguals as they *become* bilingual (i.e. emerging bilinguals). The general assumption in the literature has been that frequent use of inhibitory control, involved in language selection, has conferred generalised advantages in bilinguals' EF (Bialystok & Craik, 2010). However, when considering *the competition model*, proposed by Hernandez et al. (2005), an explanation for the differences between early and late bilinguals may become more evident.

According to Hernandez et al. (2005), early and late bilinguals differ in their L2 learning in two important ways: (1) L2 has parasitic associations with L1 for late bilinguals but not early bilinguals and (2) brain plasticity is greater for early bilinguals. In order to overcome the parasitic interference from L2 and decaying plasticity, late bilinguals must engage in metacognitive strategies, such as rehearsal, recoding and imagery. Intuitively, late bilinguals, who achieve greater L2 control, would also have more controlled use of their metacognitive strategies. Thus, it is possible that late bilinguals' frequent use of these metacognitive strategies drives advantages in EF. Support for this proposal comes from the findings of Festman, Rodriguez-Fornells, and Münte (2010), who showed that late bilinguals with greater language control (i.e. non-switchers) performed better on EF measures than late bilinguals with less language control (i.e. switchers). Yet, before definitive claims can be made about the direction of the relationship between language development and EF, additional research must be conducted to rule out alternative hypotheses.

In the current study, we found differing associations between language and EF in early and late bilinguals. Participants' other-language proficiency was negatively associated with English vocabulary, but *only* for the late bilinguals. Consistent with the predictions of the *competition model* (Hernandez et al., 2005), early and late bilinguals varied in the ways interference influenced their performance during the task. For the late bilinguals, better phonological skills were associated with improved English vocabulary, suggesting that late bilinguals with greater metalinguistic skills were able to learn languages more readily.

CONCLUSIONS AND LIMITATIONS

Evidence of a bilingual advantage in EF continues to be ephemeral. In our examination of differences between early and late bilinguals as well as monolinguals, no differences between groups were observed in inhibition (i.e. perservative errors) and shifting abilities (i.e. switching). Late bilinguals did exhibit a disadvantage in accuracy relative to the monolinguals and early bilinguals. However, early bilinguals performed either equivalently to the monolinguals or *worse* than the late bilinguals.

Although important insights can be gleaned from the current study, several limitations must be acknowledged. First, although the overall sample is large (N = 105), the number of late bilinguals in the sample is relatively small (n = 23). As Paap and Greenberg (2013) have noted, comparisons with small groups raise concerns about Type 1 error. Thus, caution must be used when interpreting and generalising the current findings. Second, the current study used a single task of EF, the ACNNT. Since past research has indicated that not all measures of EF correlate with one another (e.g. Miyake & Friedman, 2012), the findings of the current study must be replicated with additional EF measures that tap into similar cognitive processes, before strong theoretical claims can be made. Third, Zelazo et al. (2004) considered the adjusted perservative errors to be the primary indicator of EF ability for the ACNNT. The other measures (i.e. proportion correct, switching costs) used in this study are derived and may be impure assessments of EF. Given the fact that the measures correlate with one another and perservative errors they cannot, in our view, be ignored either. Fourth, similar to Krizman, Marian, Shook, Skoe, and Kraus (2012), the EF task used in the current study required bilinguals to process auditory information (i.e. number words). As a result, it is possible that the task placed increased demands on the bilinguals' working memory. And finally, although previous research has verified the reliability of self-report measures with bilinguals (e.g. Marian, Blumenfeld, & Kaushanskaya, 2007), bilinguals' self-reported other-language proficiency may be less reliable than standardised proficiency measures, an issue that must be resolved with additional research.

Taken together, the current study provides additional evidence that fundamental differences in the way individuals learn languages impacts cognition. The current study also raises important questions about the role of language exposure and development on EF. Future research examining cognitive and language development in young emerging bilinguals (e.g. Carlson & Meltzoff, 2008) may provide further insight into the relationship between language and EF and the degree to which the cognitive abilities that underlie EF are mediated by language (Jacques & Zelazo, 2001).

Original manuscript received September 2013
Revised manuscript received August 2014
Revised manuscript accepted August 2014
First published online September 2014

REFERENCES

Abutalebi, J. (2008). Neural aspects of second language representation and language control. *Acta Psychologica, 128*, 466–478. doi:10.1016/j.actpsy.2008.03.014

Altepeter, T. S., & Johnson, K. A. (1989). Use of the PPVT-R for intellectual screening with adults: A caution. *Journal of Psychoeducational Assessment*, *7*, 39–45. doi:10.1177/073428298900700104

Anderson, P. (2002). Assessment and development of executive function (EF) during childhood. *Child Neuropsychology, 8*, 71–82. doi:10.1076/chin.8.2.71.8724

Beaujean, A. A., & Osterlind, S. J. (2008). Using item response theory to assess the Flynn Effect in the National Longitudinal Study of Youth 79 Children and Young Adults data. *Intelligence, 36*, 455–463. doi:10.1016/j.intell.2007.10.004

Bell, N. L., Lassiter, K. S., Matthews, T. D., & Hutchinson, M. B. (2001). Comparison of the Peabody Picture Vocabulary Test—Third Edition and Wechsler Adult Intelligence Scale—Third Edition with university students. *Journal of Clinical Psychology*, *57*, 417–422. doi:10.1002/jclp.1024

Bialystok, E. (2001). *Bilingualism in development: Language, literacy, and cognition*. New York, NY: Cambridge University Press.

Bialystok, E. (2009). Bilingualism: The good, the bad, and the indifferent. *Bilingualism: Language and Cognition, 12,* 3–11. doi:10.1017/S1366728908003477

Bialystok, E., & Craik, F. I. M. (2010). Cognitive and linguistic processing in the bilingual mind. *Current Directions in Psychological Science, 19*, 19–23. doi:10.1177/0963721409358571

Bialystok, E., Craik, F. I. M., Klein, R., & Viswanathan, M. (2004). Bilingualism, aging, and cognitive control: Evidence from the Simon task. *Psychology and Aging, 19*, 290–303. doi:10.1037/0882-7974.19.2.290

Bialystok, E., Craik, F. I. M., & Luk, G. (2008). Cognitive control and lexical access in younger and older bilinguals. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 34*, 859–873. doi:10.1037/0278-7393.34.4.859

Bialystok, E., & Martin, M. M. (2004). Attention and inhibition in bilingual children: Evidence from the dimensional change card sort task. *Developmental Science, 7*, 325–339. doi:10.1111/j.1467-7687.2004.00351.x

Blumenfeld, H. K., & Marian, V. (2013). Parallel language activation and cognitive control during spoken word recognition in bilinguals. *Journal of Cognitive Psychology, 25*, 547–567. doi:10.1080/20445911.2013.812093

Carlson, S. M., & Meltzoff, A. N. (2008). Bilingual experience and executive functioning in young children. *Developmental Science, 11*, 282–298. doi:10.1111/j.1467-7687.2008.00675.x

Costa, A., Hernández, M., & Sebastián-Gallés, N. (2008). Bilingualism aids conflict resolution: Evidence from the ANT task. *Cognition, 106*, 59–86. doi:10.1016/j.cognition.2006.12.013

Craik, F. I. M., & Bialystok, E. (2006). Cognition through the lifespan: Mechanisms of change. *Trends in Cognitive Sciences, 10*, 131–138. doi:10.1016/j.tics.2006.01.007

DeKeyser, R. (2000). Negative items and negation strategies in nonnative Italian. *Studies in Second Language Acquisition, 22*, 399–440. doi:10.1017/S0272263100003053**.**

Duñabeitia, J. A., Hernández, J. A., Antón, E., Macizo, P., Estévez, A., Fuentes, L. J., & Carreiras, M. (2014). The inhibitory advantage in bilingual children revisited: Myth or reality? *Experimental Psychology, 61*, 234–251. doi:10.1027/1618-3169/a000243

Dunn, L. M., & Dunn, L. M. (1981). *The Peabody Picture Vocabulary Test-Revised*. Circle Pines, MN: American Guidance Service.

Dunn, L. M., & Dunn, L. M. (1997). *PPVT-III: Peabody Picture Vocabulary Test. Form IIIB*. Circle Pines, MN: American Guidance Service.

Dunn, L. M., & Dunn, D. M. (2007). *Peabody Picture Vocabulary Test, Fourth Edition: Manual*. Minneapolis, MN: Pearson Assessments.

Festman, J., Rodriguez-Fornells, A., & Münte, T. F. (2010). Individual differences in control of language interference in late bilinguals are mainly related to general executive abilities. *Behavioral and Brain Functions*, *6*, 5. doi:10.1186/1744-9081-6-5

Gathercole, S. E., & Baddeley, A. D. (1990). The role of phonological memory in vocabulary acquisition: A study of young children learning new names. *British Journal of Psychology, 81*, 439–454. doi:10.1111/j.2044-8295.1990.tb02371.x

Green, D. W. (1998). Mental control of the bilingual lexico-semantic system. *Bilingualism: Language and Cognition, 1*, 67–81. doi:10.1017/S1366728998000133

Hernandez, A., Hofmann, J., & Kotz, S. A. (2007). Age of acquisition modulates neural activity for both regular and irregular syntactic functions. *Neuroimage, 36*, 912–923. doi:10.1016/j.neuroimage.2007.02.055

Hernández, M., Martin, C. D., Barceló, F., & Costa, A. (2013). Where is the bilingual advantage in task-switching? *Journal of Memory and Language, 69*, 257–276. doi:10.1016/j.jml.2013.06.004

Hernandez, A., Li, P., & MacWhinney, B. (2005). The emergence of competing modules in bilingualism. *Trends in Cognitive Sciences, 9*, 220–225. doi:10.1016/j.tics.2005.03.003

Hilchey, M. D., & Klein, R. M. (2011). Are there bilingual advantages on non-linguistic interference tasks? Implications for the plasticity of executive control processes. *Psychonomic Bulletin and Review, 18*, 625–658. doi:10.3758/s13423-011-0116-7

Hull, R., & Vaid, J. (2007). Bilingual language lateralization: A meta-analytic tale of two hemispheres. *Neuropsychologia, 45*, 1987–2008. doi:10.1016/j.neuropsychologia.2007.03.002

Jacques, S., & Zelazo, P. D. (2001). The Flexible Item Selection Task (FIST): A measure of executive function in preschoolers. *Developmental Neuropsychology, 20*, 573–591. doi:10.1207/S15326942DN2003_2

Johnson, J. S., & Newport, E. L. (1989). Critical period effects in second language learning: The influence of maturational state on the acquisition of English as a second language. *Cognitive Psychology, 21*, 60–99. doi:10.1016/0010-0285(89)90003-0

Kaushanskaya, M., & Marian, V. (2007). Age-of-acquisition effects in the development of a bilingual advantage for word learning. *Proceedings of the Boston University Conference on Language Development*.

Kim, K. H. S., Relkin, N. R., Lee, K. M., & Hirsch, J. (1997). Distinct cortical areas associated with native and second languages. *Nature, 388*, 171–174. doi:10.1038/40623

Kousaie, S., & Phillips, N. A. (2012). Conflict monitoring and resolution: Are two languages better than one? Evidence from reaction time and event-related brain potentials. *Brain Research, 1446*, 71–90. doi:10.1016/j.brainres.2012.01.052

Krizman, J., Marian, V., Shook, A., Skoe, E., & Kraus, N. (2012). Subcortical encoding of sound is enhanced in bilinguals and relates to executive function advantages. *PNAS, 109*, 7877–7881. doi:10.1073/pnas.1201575109

Linck, J. A., Hoshino, N., & Kroll, J. F. (2008). Cross-language lexical processes and inhibitory control. *Mental Lexicon, 3*, 349–374. doi:10.1075/ml.3.3.06lin

Linck, J. A., Kroll, J. F., & Sunderman, G. (2009). Losing access to the native language while immersed in a second language: Evidence for the role of inhibition in second-language learning. *Psychological Science, 20*, 1507–1515. doi:10.1111/j.1467-9280.2009.02480.x

Luk, G., De Sa, E., & Bialystok, E. (2011). Is there a relation between onset age of bilingualism and enhancement of cognitive control? *Bilingualism: Language and Cognition, 14*, 588–595. doi:10.1017/S1366728911000010

Marcovitch, S., & Zelazo, P. D. (2009). A hierarchical competing systems model of the emergence and early development of executive function. *Developmental Science*, *12*, 1–25. doi:10.1111/j.1467-7687.2008.00754.x

Marian, V., Blumenfeld, H. K., & Kaushanskaya, M. (2007). The language experience and proficiency questionnaire (LEAP-Q): Assessing language profiles in bilinguals and multilinguals. *Journal of Speech, Language, and Hearing Research, 50*, 940–967. doi:10.1044/1092-4388(207-067)

Maxwell, J. K., & Wise, F. (1984). PPVT IQ validity in adults: A measure of vocabulary, not of intelligence. *Journal of Clinical Psychology, 40*, 1048–1053.

Mechelli, A., Crinion, J. T., Noppeney, U., O'Doherty, J., Ashburner, J., Frackowiak, R. S., & Price, C. J. (2004). Structural plasticity in the bilingual brain: Proficiency in a second language and age at acquisition affect grey matter density. *Nature, 431*, 757–757. doi:10.1038/431757a

Morton, J. B., & Harper, S. N. (2007). What did Simon say? Revisiting the bilingual advantage. *Developmental Science, 10*, 719–726. doi:10.1111/j.1467-7687.2007.00623.x

Miyake, A., & Friedman, N. P. (2012). The nature and organization of individual differences in executive functions: Four general conclusions. *Current Directions in Psychological Science, 21*, 8–14. doi:10.1177/0963721411429458

Müller, U., Zelazo, P. D., Lurye, L. E., & Liebermann, D. P. (2008). The effect of labeling on preschool children's performance in the Dimensional Change Card Sort Task. *Cognitive Development, 23,* 395–408. doi:10.1016/j.cogdev.2008.06.001

Neter, J., Kutner, M., Wasserman, W., & Nachtscheim, C. J. (1996). *Applied linear statistical models* (4th ed.). New York, NY: McGraw-Hill/Irwin.

Paap, K. R., & Greenberg, Z. I. (2013). There is no coherent evidence for a bilingual advantage in executive processing. *Cognitive Psychology, 66*, 232–258. doi:10.1016/j.cogpsych.2012.12.002

Pelham, S., & Abrams, L. (2014). Cognitive advantages and disadvantages in early and late bilinguals. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 40*, 313–325. doi:10.1037/a0035224

Perani, D., Abutalebi, J., Paulesu, E., Brambati, S., Scifo, P., Cappa, S. F., & Fazio, F. (2003). Role of age of acquisition and language usage in early, highly proficient bilinguals: An fMRI study during verbal fluency. *Human Brain Mapping, 19*, 170–182. doi:10.1002/hbm.10110

Prior, A., & Gollan, T. (2011). Good language-switchers are good task-switchers: Evidence from Spanish–English and Mandarin–English bilinguals. *Journal of International Neuropsychological Society, 17*, 1–10.

Prior, A., & MacWhinney, B. (2010). A bilingual advantage in task switching. *Bilingualism: Language and Cognition, 13*, 253–262. doi:10.1017/S1366728909990526

Rouder, J. N., Speckman, P. L., Sun, D., Morey, R. D., & Iverson, D. (2009). Bayesian *t* tests for accepting and rejecting the null hypothesis. *Psychonomic Bulletin & Review, 16*, 225–237. doi:10.3758/PBR.16.2.225

Tao, L., Marzecova, A., Taft, M., Asanowicz, D., & Wodniecka, Z. (2011). The efficiency of attentional networks in early and late bilinguals: The role of age of acquisition. *Frontiers in Psychology, 2*, 123. doi:10.3389/fpsyg.2011.00123

Wagner, R. K. Torgensen, J. K., & Rashotte, C. A. (1999). *Comprehensive Test of Phonological Processing (CTOPP*). San Antonio, TX: Pearson Education Inc.

Watson, C. G., & Severson, R. A. (1976). The Peabody Picture Vocabulary Test as a measure of intelligence in children with palatal problems. *The Cleft Palate Journal*, *13*, 367–370.

Williams, K. T. (2007). *Expressive Vocabulary Test, Second Edition*. Circle Pines, MN: AGS Publishing.

Zelazo, P. D. (2006). The Dimensional Change Card Sort (DCCS): A method of assessing executive function in children. *Nature Protocols, 1,* 297–301. doi:10.1038/nprot.2006.46

Zelazo, P. D., Craik, F. I. M., & Booth, L. (2004). Executive function across the life span. *Acta Psychologica, 115,* 167–183. doi:10.1016/j.actpsy.2003.12.005