Psychological Bulletin
2017, Vol. 143, No. 3, 233–262


0033-2909/17/$12.00 http://dx.doi.org/10.1037/bul0000099

# The Bilingual Adaptation: How Minds Accommodate Experience

Ellen Bialystok
York University

According to some estimates, more than half of the world's population is multilingual to some extent. Because of the centrality of language use to human experience and the deep connections between linguistic and nonlinguistic processing, it would not be surprising to find that there are interactions between bilingualism and cognitive and brain processes. The present review uses the framework of experience-dependent plasticity to evaluate the evidence for systematic modifications of brain and cognitive systems that can be attributed to bilingualism. The review describes studies investigating the relation between bilingualism and cognition in infants and children, younger and older adults, and patients, using both behavioral and neuroimaging methods. Excluded are studies whose outcomes focus primarily on linguistic abilities because of their more peripheral contribution to the central question regarding experience-dependent changes to cognition. Although most of the research discussed in the review reports some relation between bilingualism and cognitive or brain outcomes, several areas of research, notably behavioral studies with young adults, largely fail to show these effects. These discrepancies are discussed and considered in terms of methodological and conceptual issues. The final section proposes an account based on "executive attention" to explain the range of research findings and to set out an agenda for the next steps in this field.

*Keywords:* bilingualism, executive function, attention, cognitive development, cognitive aging



A transformational change in cognitive neuroscience in recent decades has come from widespread evidence for lifelong experience-related neuroplasticity and its role in understanding brain and cognitive systems (Pascual-Leone, Amedi, Fregni, & Merabet, 2005). Although it was known for a long time that enriching experience had positive effects on rat behavior and learning (Hebb, 1949), the extension and application of this capacity to humans, particularly in adulthood, was not recognized until recently. Research with animals has documented the details of these adaptive brain changes and the experiences that lead to them (review in Kolb et al., 2012). These studies have shown, for example, that rats reared in stimulating environments have greater cortical density (Rosenzweig, Krech, Bennett, & Diamond, 1962) and perform better in learning tasks (Petrosini et al., 2009) than rats raised in standard lab cages. Similarly, rats reared in social groups show more hippocampal neurogenesis and better learning than rats reared in isolation (Lu et al., 2003). More dramatically, interactions between the genome and the environment lead to changes in DNA methylation that allow these changes to be transmitted to the offspring of the rats who had been raised in stimulating environments, supporting the crucial role of epigenetic factors in brain and cognitive outcomes (Mychasiuk et al., 2012). It is abundantly clear that the environment plays a crucial role in the brain and mental development of animals.

This work was partially supported by grant R01HD052523 from the NIH National Institute of Child Health and Human Development, grant A2559 from the Natural Sciences and Engineering Research Council of Canada, and grant R21AG048431 from the NIH National Institute on Aging.

Correspondence concerning this article should be addressed to Ellen Bialystok, Department of Psychology, York University, 4700 Keele Street, Toronto, ON, Canada M3J 1P3. E-mail: ellenb@yorku.ca

The intriguing possibility is that experience has the potential to similarly modify brain structure and cognitive systems in humans. Some experiences are well known to impact brain and cognitive development, especially for children. Primary among these is socioeconomic status, where impoverished environments affect a variety of cognitive systems as well as brain volume and structure (Noble, Houston, Kan, & Sowell, 2012). For adults, formal education has been shown to affect both brain structure and cognitive level, especially in terms of slowing cognitive decline with aging (Kramer, Bherer, Colcombe, Dong, & Greenough, 2004). Beyond systemic environmental effects, engagement in particular activities can also modify brain and cognition in humans. These activities include music training (Lappe, Trainor, Herholz, & Pantev, 2011; Peretz & Zatorre, 2005; Rauscher, Shaw, & Ky, 1993), experience in spatial navigation (Maguire et al., 2000), extended engagement in action video game playing (Bavelier & Davidson, 2013; Green & Bavelier, 2003; Karle, Watter, & Shedden, 2010; Riesenhuber, 2004), and even brief training in juggling (Draganski et al., 2004).

## The Uniqueness of Bilingualism

If experience can shape brain structure and cognitive ability, then bilingualism is a prime candidate for such effects. Language use is the most intense, sustained, and integrative experience in which humans engage. The intensity reflects the role that language has in all our activities, not only for verbal communication but also for conceptualizing and interpreting ongoing experience. Semantic networks are invoked each time an event is understood or a memory is formed. Language use is sustained because of all human activities, none consumes the proportion of waking (and perhaps nonwaking) time that language does. Other activities with known neuroplastic benefits, such as musical performance, can only be undertaken some finite number of hours per day; language use in all its forms has no limit so from the perspective of dose-related effects, it is unrivalled. Finally, language use is integrative; using language engages most of the brain, including frontal, temporal, and parietal lobes, as well as some posterior regions (Friederici, 2011). This extensive involvement of brain centers increases the possibility that experience-related effects found for language use have the potential to generalize beyond language because the experience itself involves more than just language-specific processes.

Support for the possibility that bilingualism can lead to changes in brain and cognitive systems comes from evidence for structural brain changes associated with learning a foreign language. In an extensive review of the literature, Li, Legault, and Litcofsky (2014) describe the reliable differences in brain structure for both grey matter density and white matter integrity after even brief periods of second-language learning. Their review considers such factors as the timing of second-language acquisition, the interaction between the languages, and the typological relation between the languages. For example, Schlegel et al. (2012) reported evidence from a 9-month longitudinal study of foreign language learning that found changes in white matter integrity in left hemisphere language areas and their right hemisphere analogs as well as in the frontal lobe over the course of the study. Other studies have found increased grey matter density in the left inferior parietal region, a primary center for language processing, was positively correlated to the participant's degree of bilingualism (Mechelli et al., 2004) and increased with the time spent in a 5-month foreign language class in a longitudinal study (Stein et al., 2012). Together these studies demonstrate that the experience of learning a second language leaves structural traces in the brain in those regions responsible for language acquisition and use.

It is not surprising that bilingualism changes the language representations and brain structure that underlie language acquisition or processing. However, the present argument goes beyond these linguistic consequences and suggests that the experience of bilingual language use leads to modifications not only in brain structure and function associated with language processing, but also in those regions and processes involved in nonverbal cognitive performance. Thus, the argument is that bilingualism is an experience that has the potential to modify brain and cognitive systems more generally, much as enriched cages do for rats and socioeconomic status does for young children.

## Language Processing in Bilinguals

Central to the argument for why bilingualism has the potential to achieve these outcomes is an explanation of how bilingual language use is different from monolingual language use. The key point comes from overwhelming evidence that both languages in a bilingual's repertoire are always active to some extent, even if one of them is not required for the current context. In some sense, this point was always known, at least intuitively: Weinreich (1953) talked about the "interference" between a bilingual's two languages. Empirical evidence came much later, with research showing cross-language facilitation and interference in simple lexical tasks (e.g., Costa, Caramazza, & Sebastian-Galles, 2000; Costa, Santesteban, & Ivanova, 2006; Dijkstra, Grainger, & van Heuven, 1999; Hermans, Bongaerts, de Bot, & Schreuder, 1998), but the significance of the insight or of the empirical findings were not fully understood. Kroll, Dussias, Bice, and Perrotti (2015) provide a detailed review of these studies and consider this evidence for joint activation to be a major discovery in the efforts to understand bilingualism. Joint activation means there is constant competition for selection, so bilinguals must control attention to language representations and language processing in a way not required for monolinguals. Without such control, there would be the constant risk of intrusion from the nontarget language, something that rarely occurs. To achieve fluent linguistic performance, therefore, bilinguals experience greater demands on a control system than do monolinguals, even when language production appears to be equivalent.

The first evidence for joint activation came from such linguistic tasks as lexical decision or picture naming in which response time for bilinguals was influenced by the inclusion of cognates to the nontarget language (e.g., Grainger, 1993). However, more dramatic evidence was reported from studies that incorporated measures of brain response. For example, in a study using electroencephalography (EEG) by Thierry and Wu (2007), Chinese–English bilinguals who were students at an English-speaking university and immersed in an English context, were asked to decide whether or not pairs of English words presented either in print or orally were semantically related. The experimental manipulation was that for half of the word pairs (equally distributed in the related and unrelated conditions) the Chinese translation of the words contained a repetition of one of the Chinese characters. Such repetition would only be apparent if the English words were translated into Chinese and then written down, activities that were well beyond the demands of the task. Reaction times and accuracy were similar for all conditions, but for both oral and written presentation, English word pairs whose translations contained an overlapping Chinese character produced a significant reduction in the N400 component of the event-related potential (ERP), indicating repetition priming (Kutas & Federmeier, 2011). Chinese monolinguals performing the task in Chinese showed the same pattern of priming but English monolinguals performing the task in English understandably showed no effect on the N400. Thus, the Chinese-English bilinguals were unconsciously influenced by their knowledge of Chinese, even though Chinese was irrelevant to this task. Morford and colleagues (Morford et al., 2011) adapted this paradigm to participants who were bilingual in English and American Sign Language (ASL) by repeating a hand shape in half the word pairs. The results again indicated priming from the repeated hand shape, even though it was irrelevant to the semantic judgment task.

Further evidence for joint activation of the nontarget language comes from an eye-tracking study by Marian and Spivey (2003). Russian-English bilinguals completed a simple task in English for which there was no reason to invoke Russian. Participants saw a display with three pictured objects and were asked to make an eye movement to the one that matched a spoken word. There were a variety of conditions but the crucial feature is that each stimulus display included three types of objects: a target object ("marker"), an object whose name was phonologically similar to the target in English ("marble"), and an object whose Russian translation was phonologically similar to the target even though there was no shared meaning (*stamp*, which is "marka" in Russian). Again, this cross-language information was wholly irrelevant to performance, but Russian-English bilinguals made initial eye movements to the cross-language distractor.

## Mechanism for Bilingual Effects

Joint activation requires that there is a mechanism for language selection to assure that use of the target language proceeds fluently. The assumptions are that this mechanism is part of a domain-general process and that the constant engagement of this process for language selection fortifies it for other purposes, including nonverbal ones (Bialystok, Craik, Green, & Gollan, 2009). Support for the notion that a domain-general system is recruited for language control comes from neuroimaging evidence showing overlap in brain networks involved in language selection and nonverbal task switching (Abutalebi & Green, 2007; De Baene, Duyck, Brass, & Carreiras, 2015; Luk, Green Abutalebi, & Grady, 2012). The nature of that domain-general system, however, remains a matter of debate.

The first speculations on how this selection system might operate were based on theoretical work by Green (1998) in which he proposed the inhibitory control (IC) model for language selection. In his model, a supervisory attention system was guided by top-down cues that led to the inhibition of the nontarget language so that language processing could proceed from the contextually and linguistically appropriate representations. The implication was that these inhibitory processes were modified by their use in language selection and affected inhibitory control in other domains. There is a large literature investigating the implications of Green's (1998) model for bilingual language processing that focuses on the role of inhibition. A discussion of those studies is beyond the scope of the present review (because of its focus on cognitive outcomes of bilingualism), but there are several comprehensive reviews of that literature (Kroll & Gollan, 2014; Kroll, Gullifer, McClain, Rossi, & Cruz Martin, 2015).

An account based on inhibition of the nontarget language became the dominant explanation for bilingual effects on cognition (e.g., Bialystok et al., 2009). The account was appealing both because it was a plausible explanation of the efficiency with which bilinguals avoided linguistic interference and because it was compatible with a highly influential model of executive function that was being developed around the same time, namely, the unity and diversity model of Miyake and colleagues (Miyake et al., 2000). Their model proposed three subcomponents of executive function, one of which was inhibition (see **Inhibition and the Executive Function**). The assumption that inhibition is at least part of the mechanism for bilingual effects on cognition has continued to frame this research. Disparities with the inhibition view will be noted throughout the present review and a reevaluation of that account is provided in **The Mechanism of Neuroplasticity in Bilingualism**.

Recognizing the limits of inhibition as an explanation, Green and Abutalebi (2013) recently expanded the IC model to provide a more detailed description of the processes responsible for bilingual language selection and the implications for cognition. In the Adaptive Control Hypothesis, they identified eight control processes (goal maintenance, conflict monitoring, interference suppression, salient cue detection, selective response inhibition, task disengagement, task engagement, and opportunistic planning) that are differentially recruited as a function of the type of interactional context for language use. The model described three such contexts—single language, dual language, and dense code-switching—each of which makes different demands on selection. The model provides an excellent framework for understanding these questions and makes detailed predictions about the cognitive and brain changes that should follow from each of the contexts. At this point, however, research supporting the claims from this model is extremely preliminary, a point the authors fully acknowledge, so a thorough evaluation must await further study. The Adaptive Control Hypothesis is discussed again briefly in **Determining Bilingualism**.

No single explanation of the control mechanisms responsible for bilingual language processing and hence cognitive effects of bilingualism has emerged as decisive. The position that will be advanced in the present review is that ultimately the best account will be one that is centered in the attention system (see discussion in **Finding the Pattern: Executive Attention**). What is clear at this time is that the bilingual mind is characterized by joint activation of the two languages and so requires selection to avoid interference from an unwanted language. Thus, the bilingual mind must adapt to this mental configuration that includes jointly activated languages for communication to proceed. If the network recruited to manage attention to the two languages is part of a nonverbal attention or selection system, then the configuration is in place for bilingualism to impact the nature or quality of nonverbal cognitive processing and presumably the brain regions on which it is based. Determining the details of that selection system will be the main challenge for future research.

## Evidence for Bilingual Effects on Cognition

There has been an enormous increase in recent years in the amount and diversity of research investigating the question of the possible impact of bilingualism for mind and brain. These studies have examined individuals at all stages of the life span and have used a variety of behavioral and imaging methods. Because of the range of the research and to understand the life span trajectory of these effects, the evidence will be presented separately by age group. For each of children (**Research With Infants and Children**), adults (**Effects of Bilingualism in Adulthood**), and patients (**Evidence From Patients**) behavioral results are described first followed by studies that include neuroimaging measures.

### Research With Infants and Children

The notion that bilingualism could have generalized consequences for nonverbal cognitive ability originated in research with children. Following widespread belief that bilingualism was detrimental for intelligence (review in Hakuta, 1986), a study by Peal and Lambert (1962) reported better performance by bilingual children than monolinguals on both verbal and nonverbal tasks. This study provided the first credible evidence that rather than being a negative force, bilingualism might instead have significant positive outcomes. Although there were problems with the Peal and Lambert study (the language groups may not have been equivalent in socioeconomic status or intelligence and the measures were broadly based intelligence tests), the results created interest in the possibility that bilingualism could affect nonverbal cognition and that the effect could be positive. Few, if any, recent studies have used the methodologies employed by Peal and Lambert, focusing instead on more precise aspects of cognitive performance using more detailed experimental methods. Nonetheless, their study was instrumental in introducing this issue as an important area for research and theory. The initial research following their study largely focused on the development of metalinguistic awareness in monolingual and bilingual children, with most studies reporting more precocious development in bilinguals (for review, Bialystok, 2001). However, the focus of the present review will be on the cognitive consequences of bilingualism, and particularly nonverbal outcomes.

**Multilingual environments in infancy.** A recent direction in investigations of the consequences of bilingualism is studies of infants being raised in environments where one or more than one languages are heard from birth. This environmental difference is associated with differences in language acquisition; for example, until about 7 months old, all infants are sensitive to the phonetic distinctions that are relevant for all natural languages but infants in bilingual environments maintain this universal sensitivity for longer (e.g., Werker & Tees, 1983, 1984). A recent study by Ferjan Ramírez, Ramírez, Clarke, Taulu, and Kuhl (2017) used magnetoencephalography (MEG) to document how the infant bilingual brain remains sensitive to phonetic distinctions from multiple languages. However, the present discussion is focused on the possibility that these environmental differences in infancy have measurable consequences for nonverbal outcomes. Three types of recent evidence converge on the conclusion that they do.

The first type of evidence examines visual attention to faces as a source of linguistic information in the first year of life. In addition to maintaining attention to phonetic distinctions, infants in bilingual environments are also able to use visual cues to determine when a speaker has switched to speaking a different language, even in the absence of auditory information. As with the ability to hear phonetic contrasts, monolingual infants can detect such changes until about 7 months old, but evidence from infants watching silent videos shows that bilingual infants continue to be able to notice when a speaker switches languages on the basis of these visual cues up to 1 year old. This finding has been demonstrated for French–English bilingual babies watching a video of a speaker switch between English and French (Weikum et al., 2007) and Spanish–Catalan bilingual babies watching the same video of a speaker switch between English and French (Sebastian-Galles, Albareda-Castellot, Weikum, & Werker, 2012), two languages they have never heard. Thus, their response is based on a coherent concept of a language system and not on an association to a particular language with which they are familiar. In both studies, monolingual babies failed to detect the language switch. Thus, infants who are building up representational systems for two languages are also learning that they are distinct and can be discriminated. Corroborating these results Pons, Bosch, and Lewkowicz (2015) used eye-tracking to show that from 8- to 12-months old, bilingually raised infants pay more attention to the mouth of a talking face than the eyes whereas monolingually raised babies generally pay more attention to the eyes. Mouth movement provides more relevant linguistic information than does information from the eyes, and in the first year, infants raised with more than one language attend to the more informative source. A recent study by Ayneto and Sebastian-Galles (2017) showed that this bias for focusing on the mouth by bilingual children extends beyond linguistic information and also characterized attention to adult faces displaying emotional states; 8-month old bilingual infants focused on the mouth more than monolingual infants but by 12 months this difference was no longer found.

The second type of evidence extends the research beyond language and examines responses of infants to nonverbal stimuli. Two studies by Kovacs and Mehler showed that bilingually raised infants at 7-months (Kovács & Mehler, 2009a) and 12-months old (Kovács & Mehler, 2009b) were able to override a habitual response to look to one side to receive a visual reward (dancing clown) and replace it with an eye movement to the opposite side when the position of the reward changed. Infants raised in monolingual environments continued to look to the original location even when the reward no longer appeared there. Similarly, a study of 6-month-old infants engaged in a visual habituation task demonstrated better stimulus encoding and recognition memory by infants raised in bilingual environments than by their monolingually raised counterparts (Singh et al., 2015). Like the Kovács and Mehler studies (2009a, 2009b), these results indicate better flexibility of attention for infants with bilingual experience.

The third source of evidence moves further into cognitive systems and reveals differences between infants from these environments in their ability to generalize memory for events in the first year of life. Infant memories are largely specific to the stimuli and context in which they were formed (Hayne, 2006) but this specificity limits concept formation and learning. The development of memory and cognitive systems requires generalizing across cues and contexts, an achievement that begins to emerge at around 12 months. In a series of studies, Brito and colleagues examined memory generalization in infants being raised in monolingual or bilingual environments. Infants in the experimental condition observed a puppet perform three simple actions and then spent 30 min playing with toys. Infants in the control condition did not observe the initial actions and began the experiment by playing with the toys. There were equal numbers of monolingual and bilingual infants in each condition. In the test phase, a different puppet was presented and the question was whether or not children would generalize the actions that had been performed by the first puppet to the new puppet. The results showed that bilingual children made this connection significantly more often than monolingual children, and that none of the children in the control condition performed these actions on the new puppet. The results indicate memory generalization across cues by bilingual infants than monolingual infants at 6 months (Brito & Barr, 2014) and at 18 months (Brito & Barr, 2012). Moreover, these results were replicated for 18-month old infants whose home languages included two similar languages, two typologically different languages, or three languages; all three groups outperformed comparable monolinguals on this task (Brito, Sebastian-Galles, & Barr, 2015). This language group difference in memory generalization was replicated in a study of 24-month old infants, with better performance by the bilingual group, but there were no differences between infants in the two language groups on cued recall, working memory, emotional responsiveness, or productive vocabulary (Brito, Grenell, & Barr, 2014). Thus, across all these experiments, bilingual infants showed greater memory generalization than monolingual infants, with no other differences between groups.

These studies examining detection of language switches, visual response to spatial position for reward, and memory generalization converge on the interpretation that in the first 2 years of life infants being raised in multilingual environments display different patterns of visual attention from those raised in monolingual homes. This research provides an important constraint on the explanations for bilingual effects on cognition because these infants have essentially no productive proficiency in language. Nonetheless, bilingual infants realize that a speaker has changed languages even if they have never heard either of the languages, possibly because of their focus of attention on the mouth rather than the eyes while watching speech. Bilingual infants show more flexible control over attention and can learn a new response to replace one that has been previously rewarded, showing as well better encoding of stimuli. Finally, bilingual infants show better ability to extract relevant features from visual stimuli so they can be generalized to form new categories beginning at 6-months old. Together these findings suggest that early exposure to a bilingual environment promotes the earlier development of a flexible attention system. Although it is not clear what is entailed by these proposed differences in attention, the hypothesis regarding the superior ability of bilinguals to inhibit attention to misleading stimuli based on experience inhibiting the nontarget language is not a viable explanation for the evidence found in the first 2 years of life.

**Cognitive processing in childhood.** Most of the research on the cognitive consequences of bilingualism began by studying young children. This is a large body of literature and has been reviewed elsewhere (Barac, Bialystok, Castro, & Sanchez, 2014) and subjected to a meta-analysis showing effect sizes ranging from small to large across studies (Adesope, Lavin, Thompson, & Ungerleider, 2010) so only highlights of that literature will be discussed here. In the majority of studies, young children were presented with tasks that involved various kinds of conflict or required some form of switching between tasks or responses. The general finding is that bilingual children perform these tasks better than monolingual children, although there are exceptions that will be discussed. Because the early research was motivated by the notion that the source of bilingual differences in cognitive processing was generalization from practice with inhibition of the nontarget language, the assumption was that these effects would not be found in children younger than about 4-years old because their experience with language use was limited. However, more recent research has reported these patterns in children as young as 2-years (Bialystok, Barac, Blaye, & Poulin-Dubois, 2010a; Poulin-Dubois, Blaye, Coutya, & Bialystok, 2011). Together with the infant studies, these results cast doubt on the role of inhibition of a nontarget language as a likely source of processing differences in bilinguals. Although it is theoretically possible that infants and toddlers actually inhibit the emerging nontarget representational system while watching or listening to speech in one of their environmental languages, the explanation seems unlikely.

A variety of tasks and methods has been used in this literature but this review will focus on those that are most relevant for the hypothesis that bilingualism has consequences for cognitive development, in particular, the implications for executive function or attention control. Thus, studies that are primarily concerned with the role of bilingualism in aspects of language acquisition, metalinguistic awareness, or cognitive ability not broadly considered part of executive function will not be reviewed. The following three sections will discuss evidence from studies based on standard models of executive function, concepts of flexibility, and a small set of studies that have used neuroimaging methods.

***Executive functioning in monolingual and bilingual children.*** Most of these tasks assessing executive function in children are interpreted as tests of inhibition so are particularly relevant for evaluating the original interpretation that inhibition is at the core of the mechanism that distinguishes bilingual from monolingual cognition. One of the most common tasks of this type is the flanker task introduced by Eriksen and Eriksen (1974) and adapted by Fan et al. (2002) as the attention network task (ANT) to distinguish among three attention networks, namely, executive control, alerting, and orienting. The ANT task was subsequently adapted by Rueda et al. (2004) to create a children's version in which the stimuli are a horizontal line of fish and the child's task is to "feed" the center fish by pressing a response key indicating whether the fish is facing left or right. As with the standard task, the manipulation is that the four flanking fish can be pointing in the same (congruent trials) or opposite (incongruent trials) direction relative to the center fish.

In an early study with this task, Yang, Yang, and Lust (2011) presented the children's ANT to 4.5-year-olds who were bilingual English–Korean children in the United States and compared their performance to monolingual English speakers in the United States and monolingual Korean speakers in both the United States and Korea. The bilingual children outperformed the two monolingual groups on both speed and accuracy. In a follow-up study, 5.5-year old Korean–English bilingual children in the United States obtained accuracy scores that were comparable with adults (Yang & Yang, 2016). Similarly, Yoshida, Tran, Benitez, and Kuwabara (2011) studied 3-year-olds and found that better flanker performance by bilinguals was also related to better word learning. Kapa and Colombo (2013) tested children across a wide age range who averaged 10-years old and showed that bilinguals performed the task significantly faster than monolinguals but that accuracy was equivalent in the two groups, possibly because the task was too easy for the older children. Finally, some studies have used the standard adult version of a flanker task in which the stimuli are arrows or chevrons and reported similar effects. Poarch and Van Hell (2012) tested 7-year-olds and found that bilinguals performed the task faster than monolinguals (in most conditions) and Poarch and Bialystok (2015) tested 9-year olds and obtained a similar result.

A task similar to the flanker task but used less often in this research is the Simon task. Like the flanker, incongruent trials introduce a cue that interferes with the correct response. Stimuli are associated with a key press, with each response key positioned on one side of the display monitor. The stimuli are presented on one side of the display such that half the time the stimulus display position corresponds to the position of the response key (congruent trials) and half the time it does not (incongruent trials). Effortful attention and control are required to overcome the tendency to respond on the same side as the stimulus presentation. Bilingual children perform this task better than monolinguals at 5-years old (Martin-Rhee & Bialystok, 2008), 5.5-years old (Morales, Calvo, & Bialystok, 2013), 6-years old (Bialystok, Martin, & Viswanathan, 2005a), 7-years old (Poarch & Van Hell, 2012), and 5–9 year olds who varied in their degree of bilingualism (second-language proficiency) with more bilingualism associated with better performance (Tse & Altarriba, 2014).

Some studies using these tasks have not found these effects. Carlson and Meltzoff (2008) tested 6-year-olds who were monolingual, bilingual, or attending a language immersion program and found no significant difference in performance on the flanker task, although they did show better bilingual performance on other conflict tasks in their battery. Two studies by another group also failed to find performance differences attributable to language background on the children's ANT (Anton et al., 2014) or a Stroop task (Dunabeitia et al., 2014). These studies both included children over a 6-year age range from approximately 6- to 12-years old (possibly the same children in both studies reducing the independence of the contributions), and the unusually wide age range might be part of the reason that the results are different from those found in other studies. Similarly, Gathercole et al. (2014) reported data from a large sample that covered the entire life span (3-year-olds to older adults) representing four language "configurations" based on language dominance and home language in English-speaking communities. They found better performance by monolinguals and English-dominant participants, although only for some of the comparisons. However, the structure of the sample in terms of the language configurations was largely uncontrolled and no information was provided about participants in terms of social class, education, or other relevant measures, except that monolinguals were from England and all other groups were from Wales.

The flanker and Simon tasks are generally considered to be assessments of inhibition, but other tasks that measure a different aspect of inhibition show different results. In the flanker and Simon tasks, inhibition is in the requirement to avoid attending to a distracting cue, but for another group of executive function, inhibition is in the requirement to suppress a prepotent response and for these tasks, the results are different. These tasks include such paradigms as gift delay (refrain from opening an attractive gift box when left alone), go/no-go paradigms (resist pressing a key when a specific stimulus appears), and to some extent, day-night tasks in which the child must name a picture (e.g., sun) with an opposite name ("night") and inhibit the overlearned association to respond with "day." These tasks generally do not show performance differences between monolingual and bilingual children (Barac, Moreno, & Bialystok, 2016; Bonifacci, Giombini, Bellocchi, & Contento, 2011; Carlson & Meltzoff, 2008; Engel de Abreu et al., 2012; Esposito, Baker-Ward, & Mueller, 2013; Martin-Rhee & Bialystok, 2008) although in all those studies, bilinguals did outperform monolinguals in tasks that assessed the type of inhibition involved in the flanker or Simon tasks. This dissociation in the response patterns between two types of tasks widely considered to be tests of inhibition casts doubt on the utility of the concept of inhibition as a mechanism for the bilingual effects on cognition. It also challenges the notion that inhibition is a single factor in conceptions of the executive function.

These studies are almost exclusively based on between-groups comparisons that require assumptions about the equivalence of the groups. Four studies have taken a different approach and examined the relation between bilingualism and executive function performance within the same children as a function of their level of bilingualism. The first is a longitudinal study that tested children at 24 and 31 months and found that children who became more bilingual over this period showed the largest advantage over monolingual children performing a battery of executive function tasks at 31 months (Crivello et al., 2016). The second is also a longitudinal study that studied children over a 1-year period between 9- and 10-years old and showed that level of bilingualism predicted the increase in level of executive control within the same children (Riggs et al., 2014). Third, in a sample of low socioeconomic status bilingual children who were 8- to 10-years old, degree of bilingualism predicted performance on executive function tasks with no contributing prediction from any other background variable (Thomas-Sunesson, Hakuta, & Bialystok, in press). Finally, a study of children in immersion education programs also indicated that performance on executive function tasks from about 7- to 10-years old was predicted by their degree of bilingualism (Bialystok & Barac, 2012).

To summarize, the majority of research with children based on tasks that are used in the investigation of executive functioning show that bilinguals generally perform better than comparable monolinguals. There are a few studies that show no differences between groups but three of those studies examine an unusually large age range without convincing control over the role of age in performance. Studies that are based on response inhibition (e.g., go/no-go task) rather than conflict resolution (e.g., flanker task) generally show no difference between groups even though both processes are considered to be measures of inhibition.

***Flexibility, switching, and monitoring of attention in children.*** Some studies have considered executive control in terms of constructs such as flexibility, switching, and monitoring. All of these concepts entail inhibition, updating, and shifting but they are not partitioned into those subprocesses because the tasks used in this type of research involve all of them. In these tasks, children need to selectively attend to specific information, often in the context of misleading or irrelevant information that may need to be ignored (inhibited), and switch between responses.

One task that has been used in this research is the Dimensional Change Card Sort Task developed by Zelazo, Frye, and Rapus (1996). Children are asked to sort a set of two-dimensional cards (e.g., red trucks) by one dimension (e.g., color) then resort the same card by the other dimension (e.g., shape). The ability to perform the postswitch classification emerges gradually from about 3- to 5-years old. Although the task requires some type of executive function, the requirement is not clearly attributable to inhibition. Children need to selectively attend to the relevant dimension, inhibit attention to the other feature, hold a sorting rule in mind and update it for the postswitch phase, and override the response established in the preswitch phase to individual stimulus cards. Several studies have demonstrated better performance in this task by bilingual children than by their monolingual peers (Bialystok, 1999; Bialystok & Martin, 2004; Carlson & Meltzoff, 2008; Kalashnikova & Mattock, 2014; Okanda, Moriguchi, & Itakura, 2010).

A second integrative task is one in which children need to reverse their initial interpretation of an image and see the drawing as something else. The task uses the classic "ambiguous figures," that is, drawings that have two interpretations depending on your point of view (e.g., duck–rabbit). The empirical question is to examine when children are able to abandon their original interpretation of one of these images and assign a new meaning to it by presenting increasingly explicit cues pointing to the other interpretation. In two studies, bilingual children were able to do this with fewer cues than were monolingual children (Bialystok & Shapero, 2005; Wimmer & Marx, 2014).

Other studies have used various measures to compare monolingual and bilingual children on tasks that require some unspecified notion of flexibility. Lee and Kim (2011) reported better scores from bilingual children than monolinguals on a standard test of creativity, Adi-Japha, Berberich-Artzi, and Libnawi, (2010) demonstrated more flexibility in a task requiring children to draw an "impossible" object, and Greenberg, Bellana, and Bialystok (2013) found better ability for bilingual than monolingual children to take the perspective of an observer and calculate the appearance of a complex display. Studies that show better performance by bilingual children than comparable monolinguals on false belief or theory of mind tasks may also fit into this category (Bialystok & Senman, 2004; Goetz, 2003; Kovacs, 2009; Nguyen & Astington, 2014). What is different about these tasks from those described in the previous section is that none of them is associated with a specific subprocess of executive function, such as inhibition, but rather each has a more diffuse dependence on a set of processes that are part of the general ability to control attention and integrate information from different sources. Moreover, evidence for bilingualism being the relevant factor comes from studies in which both bilingualism and country of origin are manipulated, as shown in the study by Yang et al. (2011) described in **Executive Functioning in Monolingual and Bilingual Children**. Bialystok et al. (2010a) included monolingual English-speaking children from Canada, monolingual French-speaking children from France, and bilingual children in Canada who spoke English plus a variety of other languages. Again, the two monolingual groups performed equivalently and the bilingual group outperformed both monolingual groups on a variety of executive function tasks. Bialystok and Viswanathan (2009) included bilingual children in Canada, bilingual children in India, and monolingual English-speaking children in Canada. This time, the two bilingual groups performed similarly and outperformed the monolingual group. There is no doubt that factors such as culture, national origin, and language affect performance on these tasks for children, but bilingualism appears to be independent of those influences.

**Evidence from neuroimaging in children.** Neuroimaging data from monolingual and bilingual children are limited, but the studies that exist show differences in both structural and functional measures. In some cases, these differences are not inherently better or worse for bilingual children compared to monolinguals, but in others, the differences are associated with measurably better behavioral outcomes. In general, outcomes from neuroimaging that show greater structural density in bilinguals or functional patterns in bilingual children that resemble those obtained from older children or adults are evidence for better brain development in bilinguals.

Two studies using EEG demonstrate that the ERP waveforms of bilingual children reflect greater sensitivity to stimulus change than do those of monolingual children (Barac et al., 2016; Kuipers & Thierry, 2012). Another study that used functional near-infrared spectroscopy showed that monolingual and bilingual children had different patterns of brain activation while performing a nonverbal control task, with bilingual children relying more on left hemisphere regions than monolingual children (Arredondo, Hu, Satterfield, & Kovelman, in press). Finally, two articles reporting data from a longitudinal study tracing white matter differences between monolingual and bilingual children show that between the ages of 8- and 13-years old, bilinguals had better structural connectivity on pathways associated with semantic processing and that myelination of these pathways was better for children who became bilingual at an earlier age than for those who became bilingual later (Mohades et al., 2012, 2015, see also **Brain Structure in Adulthood**).

Della Rosa et al. (2013) conducted a longitudinal study with multilingual children who were about 10 years old and tested at two points in time over approximately 1 year to investigate structural grey matter density. They found greater volume in the left inferior parietal gyrus (LIPG) in children who were more bilingual than their less bilingual peers. Children also performed a flanker task, and a score for their ability to resolve the conflict on incongruent items was entered into the analysis with their overall multilingual ability and the grey matter volume of LIPG. There was a negative correlation between the conflict score and the child's multilingual competence, with more multilingual children performing better on the flanker task. More striking, the increase in grey matter volume in the LIPG between the two testing times was positively related to the conflict score and to the child's degree multilingual competence (adjusted $R^2 = 0.44$). Children who were more multilingual or who had more multilingual ability showed larger increases in grey matter volume in the LIPG.

Some studies have also shown a relation between neuroimaging and behavioral results. In the study by Barac et al. (2016), better differentiation of the N2/P3 waveform for bilingual children performing a go/no-go task was associated with better discriminability of go and no-go trials, both indicative of more mature performance. Kuipers and Thierry (2013) recorded ERPs and pupil size in monolingual and bilingual toddlers who were presented with word-picture pairs. For unrelated pairs, bilinguals showed greater pupil dilation than monolinguals that was correlated with a decrease in N400 amplitude; that is, the larger the pupil dilation, the less negative the N400. The authors interpreted this as indicating better semantic integration for bilinguals. Monolinguals, in contrast, showed the opposite pattern in that pupil dilation was associated with more negativity on the N400. The pattern of the bilingual toddlers replicated the results from a group of monolingual adults performing the same task (Kuipers & Thierry, 2011). The interpretation was that paying attention to the unexpected stimulus interfered with semantic integration for the monolinguals but facilitated it for bilinguals. These results point to differences in attention to environmental stimuli between these two language groups.

The summary of the research with infants and children is that the development of abilities broadly associated with executive functioning is more precocious in bilingual children than in their monolingual counterparts. The majority of studies report better performance by bilingual children on a variety of tasks, although no single task serves as the gold standard and all tasks include research showing exceptions to this majority outcome. Uniformly, these exceptions are cases in which children in the two language groups did not differ from each other; no studies have reported cases in which bilingualism creates a disadvantage for children. Although the tasks themselves are very different, they all require controlled, selective, or effortful attention to perform.

## Effects of Bilingualism in Adulthood

The first article reporting cognitive consequences of bilingualism in adulthood included three experiments that compared monolingual and bilingual adults who were middle-aged (~40 years) or older (~70 years) performing a Simon task (Bialystok, Craik, Klein, & Viswanathan, 2004). The task was to press a key on one side of the monitor if a red stimulus appeared and a key on the other side if a blue stimulus appeared regardless of the position of the stimulus, creating congruent and incongruent trials. The first experiment was a small-scale pilot study including about 10 participants in each of the four groups (Age Group × Language Group) and showed faster responding by bilinguals, especially for incongruent trials. The second experiment was larger scale (64 middle-aged adults, 30 older adults) and the task included various conditions to control for response speed and working memory. The results were comparable with those in Experiment 1. Experiment 3 was a small scale study of how these patterns held up over time. Ten monolingual and 10 bilingual middle-aged adults completed 10 consecutive blocks of the task. In the early blocks, bilinguals performed significantly faster than monolinguals but by the tenth block the monolinguals had caught up and the difference disappeared. These results are consistent with the notion of practice effects or efficiency differences between groups. This article set in motion a large amount of research and drew widespread attention to bilingualism, particularly in terms of adult cognition.

**Behavioral studies of executive function in adults.** In the study by Bialystok et al. (2004), the "younger" group had a mean age of about 42 years, but most psychology research is conducted with younger adults who are around 20 years old, so subsequent research turned its attention to this group. The majority of this research used tasks that were adapted from the executive function literature.

Possibly the most commonly used task in this research is the flanker task or its ANT variation. In a large scale study, Costa, Hernandez, and Sebastian-Galles (2008) administered the ANT to 100 monolingual Spanish speakers and 100 bilingual Spanish-Catalan speakers, with an average age of 22 years. Bilinguals were faster overall, took more advantage of the alerting cues, and displayed less interference from incongruent stimuli than monolinguals. Similar results showing better performance by bilingual young adults using a version of a flanker task have been reported in different countries, with different language groups, and different cultures (Calabria, Hernandez, Martin, & Costa, 2011; Marzecova, Asanowicz, Kriva, & Wodniecka, 2013; Pelham, & Abrams, 2014; Tao, Marzecova, Taft, Asanowicz, & Wodniecka, 2011; Verreyt, Woumans, Vandelanotte, Szmalec, & Duyck, 2016; Woumans, Ceuleers, Van der Linden, Szmalec, & Duyck, 2015; Yang & Yang, 2016).

Other studies have used the Stroop task to examine performance differences between monolingual and bilingual young adults. Bialystok, Craik, and Luk (2008) administered both a Stroop and Simon task to younger and older adults who were monolingual or bilingual and found bilinguals in both age groups outperformed the monolinguals, although there was no language group difference for young adults on the Simon task. The results from the Stroop task were replicated in a subsequent study testing older and younger adults with bilinguals in both age groups outperforming the monolinguals (Bialystok, Poarch, Luo, & Craik, 2014). Two studies by Blumenfeld and Marian (2011, 2014) tested young adults and demonstrated better Stroop performance by bilinguals, although the size of the effect was small in the first study. Coderre, Van Heuven, and Conklin (2013) administered a Stroop task to young adults who were English monolinguals and two groups of Chinese–English bilinguals who differed in which was the dominant language. The results confirmed an advantage for the bilinguals but importantly showed as well significant effects of such factors as language proficiency and writing system. Finally, a study by Incera and McLennan (2016) used a novel method in which the responses were recorded by tracking the mouse movements toward the correct response. They tested three groups—monolingual English speakers, English–Spanish bilinguals, and English–Other bilinguals. The overall times to reach the correct response were similar for all three groups, but there was a significant difference in how the response was achieved. Monolinguals had faster initiation times than both bilingual groups in that they started moving the mouse sooner after trial onset, but bilinguals had faster travel times to the target once they began. There was no difference between the two bilingual groups. The authors argue that slower initiation and faster travel time is the signature of expert behavior. In a related approach, Singh and Mishra (2012, 2013) compared high- and low-proficiency Hindi-English bilinguals on a Stroop task in which the response was indicated by an eye movement to the correct target. Bilinguals showed more rapid saccades to the target in all conditions. Note, however, that a study by Bialystok, Craik, and Ryan (2006) using an antisaccade task showed better performance by both younger and older bilinguals when the response was indicated by a key press but no difference between language groups when the response was indicated by the eye movement. More research is required to clarify these conflicting patterns.

Some studies have focused not on specific tasks but on a more generalized concept of executive function, namely, conflict monitoring. Costa, Hernandez, Costa-Faidella, and Sebastian-Galles (2009) administered different versions of a flanker task to groups of monolingual and bilingual young adults. The manipulation was the likelihood of a block containing an incongruent trial, a difference that changes the need for monitoring. The bilinguals outperformed the monolinguals in conditions where the monitoring demands were high, for example, equal likelihood of congruent and incongruent trials, but there was no difference between groups when most of the trials in the block had the same valence. Conflict monitoring was also the explanation given for better bilingual performance in the AX Continuous Performance Task (AX-CPT; Braver et al., 2001). Participants are asked to identify the occurrence of the pattern A followed by X in a continuous stream of letters. The critical trials are those in which an A is followed by Y or X is preceded by B, and successful performance requires both proactive and reactive control. Morales and colleagues (Morales, Gomez-Ariza, & Bajo, 2013; Morales, Yudes, Gomez-Ariza, & Bajo, 2015) reported better performance by bilinguals than monolinguals on this task and argued that the bilinguals had greater capacity to monitor these components of executive function. Finally, as part of a larger study of conflict monitoring in sentence processing, Teubner-Rhodes et al. (2016) demonstrated better performance by bilinguals than monolinguals on a nonverbal N-back task that they describe as requiring conflict monitoring.

The final group of studies falls broadly into a category of attention tasks. One example is the antisaccade task by Bialystok et al. (2006) described above in which younger and older bilinguals were better able to direct attention to a target when there were distracting cues (although the same task based on eye movements showed no group differences). Colzato et al. (2008) administered stop signal inhibition of return, and attentional blink tasks to identify the elements of inhibitory control that were affected by bilingualism. Although there were some limitations of the design (small sample and monolinguals and bilinguals lived in different countries), the results showed significant differences between the groups in a pattern that the authors interpret as showing better goal maintenance and reactive inhibition in bilinguals. Continuing with the notion of inhibitory control, Treccani, Argyri, Sorace, and Della Sala (2009) reported larger negative priming effects in bilinguals than monolinguals, reflecting more inhibition. Loosely fitting the category of attention tasks, Prior and MacWhinney (2010) reported smaller local costs for bilinguals in a task-switching paradigm: Bilinguals could more efficiently shift attention between dimensions to select the correct response. However, a subsequent study using task switching confirmed that aspects of performance on this task were better for bilinguals than monolinguals but there was no overall reduction in switch costs (Hernández, Martin, Barceló, & Costa, 2013). Soveri, Rodriguez-Fornells, and Laine (2011) found smaller mixing costs that were negatively correlated with the amount of daily language switching reported by participants, perhaps revealing an important underlying factor in these results. Testing older adults with three tasks (Simon, trail making, and working memory), Goral, Campanelli, and Spiro (2015) reported better performance by balanced bilinguals but not unbalanced bilinguals on the Simon task. However, in a larger study of 108 participants that included younger and older monolinguals and bilinguals, bilinguals outperformed monolinguals on a Simon task in both age groups; subdividing the bilinguals into balanced and unbalanced did not change this outcome (Salvatierra & Rosselli, 2011). Finally, as in the study with children described earlier (Greenberg et al., 2013), bilingual young adults required fewer cues than monolinguals to find the alternative image in an ambiguous figure (Chung-Fat-Yim, Sorge, & Bialystok, 2017).

These studies show that both younger and older bilinguals generally outperform monolinguals on a range of tasks that fall broadly within the category of executive function. However, many studies do not show these effects, especially for young adults. Bialystok et al. (2005a) administered a Simon task to children, young adults, middle-aged adults, and older adults and found that bilinguals outperformed their monolingual age-mates in all groups except young adults, where performance was equivalent. Thus, early evidence showed that young adults performing these tasks frequently showed no effect of language experience. More recent studies have also failed to find differences between monolinguals and bilinguals performing executive function tasks. The first of the recent studies of this type was conducted by Paap and Greenberg (2013). They reported three studies in which young adults who self-identified as monolingual or bilingual performed four standard executive function tasks, namely, antisaccade, Simon, flanker, and switching. No language group contrasts were significant. A later study following the same procedure and using the same tasks (Paap & Sawi, 2014) and a third publication that presented the combined data from the first two studies (Paap, Johnson, & Sawi, 2015) showed the same results (although these studies include the same participants so do not provide an independent contribution). Other studies have also shown no behavioral differences in executive function in monolingual and bilingual young adults (Gathercole et al., 2014; Kalia, Wilbourn, & Ghio, 2014; Kousaie & Phillips, 2012b; Kousaie et al., 2014; Prior & Gollan, 2013; Scaltritti, Peressotti, & Miozzo, 2017; von Bastian, Souza, & Gade, 2016) and older adults (Antón, Fernández García, Carreiras, & Dunabeitia, 2016; de Bruin, Bak, & Della Sala, 2015; Kirk, Fiala, Scott-Brown, & Kempe, 2014).

The majority of studies showing no group differences were conducted with young adults performing simple tasks. Why would there be behavioral differences on these tasks for children and older adults but not young adults? One possibility comes from the average speed of response and standard deviation obtained for these groups. Taking the flanker task as an example, the mean reaction time (RT), including congruent and incongruent conditions, is about 500 ms, a response time that is difficult to improve through engagement in a stimulating experience. The mean RT for both children and older adults is typically longer than those for young adults allowing more room for individual differences related to a group experience to influence the outcomes. In this sense, the results from young adults for simple executive function tasks may be at ceiling levels and contain insufficient interindividual variability for group differences to emerge. For research with young adults that attempts to understand the cognitive structures involved in executive function and the effect of task manipulations on those outcomes, it is beneficial that individual experience has little effect. That may be one reason why the task designs are so simple. However, if the question is to understand individual differences more fully, then the task needs to provide the opportunity for a wider range of performance.

Other factors that may also prevent the appearance of significant differences between monolingual and bilingual young adults performing executive control tasks have been discussed elsewhere and include the selection and designation of the participants as monolingual or bilingual, the statistical methods used in the analyses, the features of the tasks, and the interpretation of the results (Bak, 2015, 2016; Bialystok, 2016; Kroll & Bialystok, 2013; Zhou & Krott, 2016). A full discussion of these factors is beyond the scope of the present review. On average studies investigating young adults tested with simple executive function tasks often fail to discriminate between these groups, but the issue is how to interpret these results and what implications these null results have for the more robust effects of bilingualism found at other points in the life span and using different approaches, including neuroimaging, even with young adults. If it turns out that there is absolutely no trace of an effect of bilingualism on young adults as some have argued (e.g., Hilchey et al., 2015) one would still need to explain how an experience that impacts cognitive and brain structure in childhood and older age recedes in young adulthood where it appears to have no consequence. More important, the studies that do show language group differences on behavioral measures of executive function would still need to be explained. This is a large and diverse body of research; failures to replicate place limits on the generalizability of these effects, but they do not erase them.

**Evidence from neuroimaging in adults.** Unlike evidence from behavioral studies, neuroimaging studies comparing monolingual and bilingual adults routinely report group differences in brain structure and function. Much of the neuroimaging research with bilinguals investigates language processing and typically examines bilinguals performing a verbal task in their two languages or switching between them. These studies point to the way two languages are represented and accessed in bilingual minds and inform psycholinguistic theories more broadly (for review see Abutalebi & Green, 2007). The present review, however, is focused on the cognitive consequences of bilingualism, so these studies will not be included.

In some of this research, neuroimaging differences between monolinguals and bilinguals are reported in the absence of behavioral differences in performance. Some researchers have argued that brain results cannot be interpreted in that case (García-Pentón et al., 2016; Paap et al., 2015). Research in cognitive neuroscience, however, takes the opposite view. For example, Dennis and Cabeza (2011) reporting the results of an functional magnetic resonance imaging (fMRI) study of learning in younger and older adults point out that equivalent behavioral performance was an asset because it allowed them to investigate neural differences having controlled for behavior. Luck (2014) makes a similar point about interpreting differences in ERP waveforms: Electrophysiology can provide evidence of "covert" mental activity that provides a reliable measure of discrimination, processing, and interpretation. By controlling for performance, brain differences can be interpreted in terms of processing efficiency (e.g., Abutalebi et al., 2012; Gold et al., 2013a), something not possible if both brain function and behavioral performance are different. Notably, recent research in cognitive neuroscience takes place in the absence of behavioral data, investigating for example the relation between resting state connectivity and potential cognitive function (e.g., Spreng et al., 2013; Vincent et al., 2008). However, in a recent commentary, García-Pentón et al. (2016) argued that evidence from brain differences between monolinguals and bilinguals were too "hazy" for any conclusions and that behavioral differences are a prerequisite to the interpretation of neuroimaging data. That assumption is out of step with current cognitive neuroscience.

***Brain structure in adulthood.*** The first study to report structural brain changes in bilingualism was conducted by Mechelli et al. (2004). They used voxel-based morphometry to measure grey matter density in three groups of young adults: monolinguals, early bilinguals who had learned their second language before the age of 5 years, and late bilinguals who had learned a second language between the ages of 10 and 15 years. They found that grey matter density was significantly greater for bilinguals than monolinguals in the LIPG, with larger effects for early bilinguals and for contrasts in the left hemisphere. In a follow-up study, a new group of bilinguals provided detailed assessments of their second-language proficiency. The results showed that grey matter density in this same region in the LIPG was positively correlated with proficiency in the second language and negatively correlated with age of acquisition of the second language. Thus, more proficiency and more experience in using a second language was associated with increased density of the LIPG. Extending this pattern into older age, Abutalebi et al. (2015) found that older bilinguals also had increased grey matter volume in the LIPG than did comparable monolinguals, although in this study the cortical density was not related to proficiency or age of acquisition. Consistent with these results, Klein et al. (2014) compared grey matter density in the LIPG for young adults who were monolingual or simultaneous bilinguals. There was again a difference between monolinguals and bilinguals, but unlike the previous studies, the greatest difference in this case was found for late bilinguals. In a prepost study of adults undergoing intense foreign language learning to become interpreters, Mårtensson et al. (2012) reported increases in hippocampal volume and cortical thickness of the LIPG (as well as in the left middle frontal gyrus and superior temporal gyrus) with no changes in area for the control group. Note that the LIPG was the region identified by Della Rosa et al. (2013) in their study with children and that in that study, grey matter volume in this region was associated with more multilingual competence and better performance on an executive function task.

The LIPG has been described as being involved in linguistic access and fluency (Poline et al., 1996), mediation of attention (Elmer, Meyer, Marrama, & Jancke, 2011), and working memory (Buchsbaum et al., 2005), and as Elmer, Hanggi, and Jancke (2014) point out, was identified long ago by Pötzl in 1925 as being the "language talent area" (cited by Elmer et al., 2014). These studies support its role in acquiring a second language and changing a fundamental structural region of the brain for bilinguals that is involved in essential cognitive processes. While it would be expected that acquisition of a new complex skill will have brain correlates, the important point in the present context is that these brain changes are also associated with aspects of superior cognitive performance.

Other studies have found structural differences between monolinguals and bilinguals in grey matter density in more frontal areas, although unlike the concentration of results for LIPG, these outcomes cover a more diverse set of regions. Frontal regions are plausible candidates for neuroplastic changes from bilingualism because of the role of the frontal lobe in the controlled processing in which bilinguals typically excel. In one of the first articles to show structural differences in frontal regions, Abutalebi et al. (2012) used voxel-based morphometry to demonstrate greater density in the dorsal anterior cingulate cortex (ACC) for bilingual than monolingual young adults. In their model describing the role of attention networks in the bilingual effects on cognition, Stocco, Yamasaki, Natalenko, and Prat (2014) focus on changes in frontal regions, particularly the frontal striatum and ACC (see also Becker, Prat, & Stocco, 2016; Stocco & Prat, 2014). Importantly, they also implicate the basal ganglia in their model, a region explored in greater depth by Krizman and colleagues (Krizman, Skoe, Marian, & Kraus, 2014; Krizman, Marian, Shook, Skoe, & Kraus, 2012) that is also central to attention and control. Similarly, Hosoda et al. (2013) conducted a 16-week foreign language training study with university students and found that the trained group showed increased grey matter volume in the inferior frontal gyrus and that this increase in volume was correlated with an increase in vocabulary following the instruction.

Because grey matter density declines with age, another approach is to compare cortical volume in relevant regions for monolingual and bilingual older adults. Abutalebi et al. (2014) reported that bilinguals showed better preserved grey matter density than comparable monolinguals in the anterior temporal pole, a region important for conceptualization. A study by Olsen et al. (2015) found no significant difference between monolingual and bilingual older adults in the anterior temporal pole but the grey matter volume of this region was significantly negatively correlated with age for monolinguals but not for bilinguals; in other words, there was a decline in grey matter density with age only for the monolinguals. The results of the Abutalebi et al. and Olsen et al. studies are consistent with the interpretation that bilingualism offers protection against loss of grey matter volume in frontal regions with aging.

Taking a different approach, Elmer et al. (2014) compared bilinguals with highly skilled simultaneous interpreters. There were no monolinguals in this study so the results cannot be directly compared to those previously discussed, but in some sense, the interpreters are "extreme bilinguals." They found differences in grey matter volume in many of the regions discussed above, including left middle-anterior cingulate gyrus and the inferior parietal gyrus, but in this case, the density was lower for the interpreters than for the bilinguals. The authors suggest that the age at which these skills were acquired, with bilinguals generally becoming fluent as children and interpreters generally becoming skilled as adults may be partly responsible for these somewhat counterintuitive results.

The studies to this point have compared grey matter structure in regions associated with the kinds of nonverbal control processes that are typically recruited by the tasks used to distinguish between monolingual and bilingual performance. In contrast, Ressel et al. (2012) examined grey matter density in Heschl's gyrus, a region involved in auditory and linguistic processing, for monolingual (Spanish) and bilingual (Spanish–Catalan) young adults. The results showed significantly greater volume in the bilinguals than in the monolinguals. Although not surprising, the results confirm that there are pervasive effects of bilingual experience on brain structure, even in areas well removed from centers involved in cognitive control.

A smaller number of studies examining structural properties of brains in monolinguals and bilinguals has focused on white matter structure to investigate the integrity of communication tracts in monolingual and bilingual brains. The first of these was conducted by Luk et al. (2011) with older adults (70 years old) and found higher fractional anisotropy (FA) in bilinguals than monolingual in tracts across the corpus callosum and extending to the superior and inferior longitudinal fasciculi. Similar results were reported by Pliatsikas, Moschopoulou, and Saddy (2015) for young adults, with higher FA found across the corpus callosum extending to inferior fronto-occipital fasciculus and the superior longitudinal fasciculi. García-Pentón et al. (2016) also found better white matter connectivity in bilingual young adults than monolinguals in similar regions, but this time in tracts in the left hemisphere. It is hard to interpret the differences in regions because all of the studies are based on small samples so the criteria for a significant contrast are high, but the evidence clearly indicates increased white matter structure in bilinguals. In the only study examining white matter structure in children (and, therefore, included here with the adult studies of white matter), Mohades et al. (2012, 2015) assessed children at two points in time, when they were 8- to 11-years old and again 3 years later and found higher FA values for bilingual children than for monolinguals in the inferior fronto-occipital fasciculus (cf., Pliatsikas et al., 2015) but not in the superior longitudinal fasciculi (cf., Luk et al., 2011). These results were found at both time points. Supporting the role of bilingualism in these effects, Mamiya, Richards, Coe, Eichler, and Kuhl (2016) reported a correlation between higher FA values in the superior longitudinal fasciculus and length of time spent in a language immersion program for Chinese students learning English.

Two further studies investigating white matter structure in older adults contribute to the overall pattern. First, a study by Olsen et al. (2015) examining white matter volume (rather than FA) found that bilinguals had greater frontal lobe white matter than did monolinguals, supporting claims for better frontal functioning in bilinguals. In fact, white matter volume in the frontal lobe was positively related to performance on a Stroop task. The second study is more anomalous: Gold, Johnson, and Powell (2013b) tested monolingual and bilingual healthy older adults (~65 years old) and found *lower* FA in the bilinguals in the inferior longitudinal fasciculus, inferior fronto-occipital fasciculus, the fornix, and multiple portions of the corpus callosum, precisely the tracts in which bilinguals had shown higher FA in other studies. It is not clear why these results are different from those reported in other studies. The authors also expected to find grey matter volume differences between monolinguals and bilinguals as reported in other studies but the outcomes were similar for the two language groups. Thus, for both grey and white matter measurements, the bilinguals in this study had less intact brain structure than previously found although both groups performed similarly on a battery of cognitive tests. The authors suggest that this pattern is consistent with the notion of greater cognitive reserve in which cognitive performance is higher than would be predicted by brain structure (cf., Schweizer et al., 2012). These issues will be pursued in **Evidence from Patients**.

Studies of brain structure have revealed a core set of findings as well as a number of peripheral or anomalous results. For grey matter, there is convergence on the finding that bilingualism and second language learning are associated with greater density in parietal and frontal regions, with some results also showing changes in the basal ganglia. These regions are involved in language processing and attentional control. For white matter, bilinguals generally show better integrity in several tracts, notably those involved with interhemisphere connectivity and anterior to medial tracts. Some studies have shown moderating influences of age of acquisition of a second language, proficiency in the second language, and other such factors, leading to a more complex view. However, even with the notable counterexamples, there is a compelling consistency in which brain regions that are involved in language processing and attention to language systems are modified by bilingualism. More important, all the regions uncovered in these studies have plausible connections to cognitive processing.

***Functional imaging during task performance.*** The most widely used procedure in cognitive neuroscience is fMRI, and this technology has also been used to investigate differences between monolingual and bilingual adults. A large portion of these studies involve bilingual participants performing a linguistic task, such as picture naming, in their two languages; those studies will not be discussed because they typically do not include monolingual participants so no conclusions about bilingual effects on brain networks can be made. The primary outcome of the studies that include a cognitive task is to show different patterns of brain activity for monolinguals and bilinguals performing the same task, measured either in terms of regions of interest or whole brain networks. In addition, differences in the degree of activity indicate the efficiency of the brain network. In these cases, regions that were used by both monolinguals and bilinguals in performing a task display less activation by bilinguals to achieve the same level of performance.

Four studies with monolingual and bilingual young adults have shown differences in functional activation while performing a simple conflict task although behavioral results showed no difference in performance level between the language groups. Bialystok et al. (2005b) administered a Simon task while MEG was recorded. Faster RT for bilinguals was associated with greater activation in left cingulate and frontal regions, whereas faster RT for monolinguals was associated with activation in middle frontal regions, indicating differences in how the task was performed. The region associated with faster responding in bilinguals overlapped with language processing areas even though the task was nonverbal. Using fMRI and a flanker task, Luk et al. (2010) reported different networks of activation for monolinguals and bilingual for incongruent (but not congruent) trials, with bilinguals relying more on frontal and subcortical regions and monolinguals on temporal and parietal networks. The more frontal recruitment for bilinguals is similar to the results found by Bialystok et al. (2005b). Also using a flanker task, Abutalebi et al. (2012) found the dorsal ACC to be important for conflict resolution in both groups, but for the bilinguals, *less* activation of this region was associated with better performance, a difference they interpreted as efficiency that comes from experience in language switching which also relies on the ACC. Similar results for more efficient use of the ACC were reported by Rodriguez-Pujadas et al. (2014) using a stop-signal task. This finding is somewhat different from the others because stop-signal is considered to be a measure of response inhibition rather than conflict resolution, and response inhibition is generally equivalent for monolinguals and bilinguals, especially in studies of children (see **Executive Functioning in Monolingual and Bilingual Children**). The study by Luk et al. (2010) included a go/no-go condition to assess response inhibition but found no performance or brain function differences between language groups. However, a recent study by Costumero et al. (2015) does show different network activation for monolinguals and bilinguals during a go/no-go task, consistent with the results of Rodriguez-Pujadas et al. (2014). ERP studies of go/no-go, also find differences between monolingual and bilingual responses, as discussed below (**EEG and Brain Response**).

Three neuroimaging studies have used nonverbal switching tasks. Gold et al. (2013a) asked younger and older adults to perform a perceptual switching task in which they had to classify stimuli by one of two dimensions while fMRI was recorded. In both age groups, bilinguals showed decreased activation in the left frontal and cingulate cortex (cf., Abutalebi et al., 2012). Crucially, the degree of activation in these regions was negatively correlated with task performance such that less activation was associated with better performance. The authors interpreted the results as evidence for the efficiency of these regions in bilinguals. A study by Becker, Prat, and Stocco (2016) used a different task but one that required frequent switching between tasks and reported converging results. For young adults, functional activation was different for monolinguals and bilinguals, with better connectivity between ACC and prefrontal cortex for bilinguals, but overall poorer accuracy with greater activation of ACC for both groups. Two studies by Rodriguez-Pujadas and colleagues using a nonverbal switching task showed that in both cases the bilinguals relied more on activation from language processing areas than monolinguals (cf., Bialystok et al., 2005b). In Garbin et al. (2010), bilinguals demonstrated a smaller switching cost than monolinguals and showed more activation of the left inferior frontal cortex for switch trials, a region involved in language switching; monolinguals had larger switch costs and showed primary activation in the ACC (cf., Abutalebi et al., 2012) but in this case there was no significant recruitment of that region by bilinguals. In Rodriguez-Pujadas et al. (2013), there again were no behavioral differences between groups but bilinguals recruited frontal regions such areas as left inferior and middle frontal gyri to a greater extent than monolinguals.

Finally, Grady and colleagues used a different approach and assessed the intrinsic resting state connectivity of networks responsible for executive function, namely, the default mode network and the frontoparietal control network (Grady, Luk, Craik, & Bialystok, 2015). The brain images are captured while the participant is at rest with eyes open but not receiving any visual input or performing any task. Participants were monolingual or bilingual older adults who were equivalent on a large number of background and cognitive measures. Intrinsic connectivity in these networks at rest is associated with better performance on executive function tasks, and this intrinsic connectivity declines with aging. The bilinguals had significantly higher connectivity in these two networks than the monolinguals, with no differences in a number of networks not involved in executive function that were investigated as a control measure. Similar results with young adults were reported by Berken et al. (2016).

The studies of functional activation and connectivity converge on three results. First, the patterns of activation, whether measured by whole brain activation (e.g., Luk et al., 2010) or regions of interest (e.g., Abutalebi et al., 2012) were different for monolinguals and bilinguals, whether behavioral performance was similar for the groups or not. Thus, monolinguals and bilinguals performing simple executive function tasks engage different brain regions or networks and importantly, these differences were closely tied to cognitive functions that have been predicted to be affected by bilingualism. This point is clearest in the study by Bialystok et al. (2005b) in which there were three groups of participants—monolinguals, French–English bilinguals, and Chinese–English bilinguals. For behavioral outcomes, Chinese-English bilinguals performed faster than the other two groups with no difference between them; for brain outcomes, the two bilingual groups produced the same results with no difference between them but both were different from the monolinguals. Faster performance for bilinguals was associated with more activation in cingulate and inferior frontal regions in the left hemisphere, but faster performance in monolinguals was associated with more activation in middle frontal regions. In the study by Luk et al. (2010), bilinguals recruited frontal, temporal and subcortical regions during incongruent trials but monolinguals activated a different network. These results support the interpretation of consistent and significant results for brain data in terms of language experience irrespective of behavioral outcomes.

Second, most of the studies found that in performing nonverbal executive function tasks, bilinguals recruited networks or regions that overlapped with those used in language processing. These tended to be more anterior and more left lateralized than the regions used by monolinguals. This pattern is important because it is consistent with claims linking these outcomes for nonverbal performance to language use experience.

Third, differences in patterns of brain activity are not inherently positive or negative but several of the studies provided evidence linking the bilingual pattern to better performance. Notably, Gold et al. (2013a) reported that bilinguals showed less activation in the ACC than monolinguals, and for both language groups less ACC activity was associated with better performance on the switching task. In the study by Abutalebi et al. (2012), this correlation was additionally linked to greater grey matter volume. Thus, these data go beyond describing differences and begin to identify strengths.

***EEG and brain response.*** Brain imaging provides rich information about brain structure and function, but the time course of cognitive processing is best revealed through electrophysiology as captured by EEG and analyzed as ERPs. Using this technique, studies with young adults have identified processing differences between monolinguals and bilinguals in the absence of behavioral differences. ERP evidence is more sensitive than behavioral RT or accuracy because it indicates the immediate brain response to specific processing demands and for most tasks can be interpreted in terms of a known signature for that task.

One task for which the ERP signature is well known is the go/no-go task. The task typically produces increased amplitude for no-go trials in the N2 and P3 components, with larger differences between them associated with better discrimination between go and no-go trials (Thorpe, Fize, & Marlot, 1996). Typically, the N2 is considered to reflect conflict processing, with larger amplitude indicating greater response to conflict, and P3 is considered to reflect stimulus categorization, with larger amplitude indicating greater allocation of resources. Two studies investigating monolingual and bilingual young adults performing a nonverbal go/no-go task reported larger amplitudes in the N2/P3 constellation for bilinguals than monolinguals, even with equivalent performance (Fernandez, Tartar, Padron, & Acosta, 2013; Moreno et al., 2014). In a training study, young adults who were monolingual were tested with a nonverbal go/no-go task in ERP at the beginning of the academic year (Sullivan et al., 2014). Following this, half of the participants followed a two-semester Introductory Spanish course and the other half did not (but was recruited from introductory psychology classes). All participants were retested at the end of the courses. Behavioral results remained equivalent for participants in the two groups, but those who had studied Spanish showed larger amplitude than the Psychology group on the P3 component at the end of the year, signaling the emergence of performance more in line with the bilingual profile for this task.

Kousaie and Phillips (2012a) administered three executive function tasks—Simon, Stroop, and flanker—to young adults who were monolingual or bilingual. As with much of this research (see **Behavioral Studies of Executive Function in Adults**), there were no differences between language groups in RT or accuracy. However, all three tasks produced group differences in the ERP waveforms, particularly for components relating to conflict monitoring, resource allocation, stimulus categorization, and error processing. All these components are based on resource recruitment and attention allocation. For example, in both the Stroop and flanker tasks, bilinguals showed an earlier P3, considered to be an index of the time needed to categorize the stimulus and therefore reflecting more efficient stimulus encoding. In contrast, monolinguals showed larger error-related negativity (ERN), considered to be an index that more control is needed. ERN is associated with activity in the ACC, a region already identified as having different structural and functional roles for monolinguals and bilinguals. However, in a surprising interpretation of the results, the authors concluded that since the ERP results were different across the three tasks but all the behavioral results were the same in that they showed no group effect, their decision was to accept the consistency of the null behavioral effect, dismiss the more complex ERP results, and conclude that there are no differences between monolinguals and bilinguals performing these tasks. However, EEG is sensitive to small processing differences in tasks, and there is no reason that the ERP waveforms should be consistent for these three different tasks that themselves make different demands on processing resources. For example, an N2 waveform in a flanker task and an N450 waveform in a Stroop task are both negative deflections in response to conflict trials that are believed to index a similar process but they differ in the timecourse and quality because of the particular demands of the tasks (Larson, Clayson, & Clawson, 2014). The ERP results from these studies provide substantial evidence for better bilingual processing in specific components of these tasks that are related to general attention or executive function.

Finally, Morales, Yudes, Gomez-Ariza, and Bajo (2015) following on earlier behavioral evidence from AX-CPT described above (Morales et al., 2013) repeated the paradigm while EEG was recorded. In both studies, bilinguals outperformed monolinguals on the behavioral measures, and in the ERP version produced waveforms consistent with better conflict monitoring, response inhibition (N2/P3), and error monitoring (ERN) than monolinguals. These are the same components and processes for which bilinguals also differed from monolinguals in the study by Kousaie and Phillips (2012a).

## Evidence From Patients

In the previous section, comparisons between monolingual and bilingual older adults were conducted for participants who were assumed to be experiencing healthy cognitive aging. Most of the studies included at least some basic assessment of cognitive level and assured that cognitive function was in the normal range and equivalent for both language groups. Overall the results showed better behavioral performance by bilinguals on nonverbal conflict tasks and diverging outcomes for brain structure and function that could be attributable to the experience of bilingualism. Following from the research with children, the interpretation is that bilingualism continues to affect cognitive and brain systems into adulthood, particularly in older age, and that the areas of enhanced bilingual performance found for children are found as well in adults. However, not all older adults experience healthy cognitive aging and instead are inflicted by neurodegenerative disease and dementia. Does lifelong bilingual experience have any effect in these cases?

It has long been known that cognitive decline with aging and dementia can be modulated by stimulating experiences, a concept known as cognitive reserve (Stern, 2002). Less severe decline in cognitive function, including cognitive decline with dementia, has been shown to be mitigated by such experiences as formal education (Bennett et al., 2003; Kramer et al., 2004; Wilson, Barnes, & Bennett, 2003), aerobic exercise (Colcombe & Kramer, 2003; Erickson et al., 2011), and stimulating leisure activities (Ferreira et al., 2015; Hall et al., 2009; Scarmeas, Levy, Tang, Manly, & Stern, 2001; Vemuri et al., 2012; Wilson et al., 2002). However, human experience is multifaceted so no single experience can possibly produce incontrovertible evidence. Thus, despite the weight of evidence for all these experiences, counterexamples exist (education: Iyer et al., 2014; Scarmeas, Albert, Manly, & Stern, 2006; Zahodne et al., 2011; aerobic exercise: Wilson et al., 2002; discussion in Kramer & Erickson, 2007). There are various reasons for the dissenting results, but it is important to understand them in the context of the majority outcomes.

In the first study reporting better performance by bilingual than monolingual adults on an executive function task, Bialystok et al. (2004) noted that the disparity between language groups was greater for the older adults than for the younger adults. This observation led to the speculation that bilingualism not only continued to boost aspects of cognitive function into adulthood but also tempered the decline of cognitive function with aging. If that were true, then bilingualism was conferring cognitive reserve in that it offered protection against age-related cognitive decline. The test of this hypothesis required evidence from patients with dementia. The question was whether or not bilingualism could mitigate the effects of neurodegenerative disease and maintain cognitive function in the presence of dementia.

The first study to investigate this possibility was a retrospective examination of patients in a memory clinic who had been diagnosed with dementia (Bialystok, Craik, & Freedman, 2007). Information collected at the initial appointment by the neurologist was used to classify patients as lifelong monolingual or bilingual. Because this classification was not part of the medical protocol at the time, 21 patients could not be confidently assigned to either language group so were excluded from the analyses. Of the 184 remaining patients (91 monolingual, 93 bilingual), two thirds met criteria for probable Alzheimer's disease (AD) and one third suffered from other dementias. For the age at which families first became aware of symptoms of dementia, the mean age was 71.4 years for monolinguals and 75.5 years for bilinguals, a difference that was highly significant. Considering instead the age at which the formal consensual diagnosis of dementia was made by the medical team, the mean age was 75.4 years for monolinguals and 78.6 years for bilinguals, a difference that was also highly significant.

Subsequent studies examining records (Craik, Bialystok, & Freedman, 2010) or testing patients (Bialystok et al., 2014) from the same clinic as used in the original study produced similar results. These results have been replicated elsewhere (e.g., Wilson et al., 2015; Woumans, Ceuleers, Van der Linden, Szmalec, & Duyck, 2015). A study by Alladi et al. (2013) conducted in India that included all levels of socioeconomic circumstances and education replicated the 4.5 year delay in symptoms of dementia initially reported by Bialystok et al. (2007). In some cases other factors interacted with the main effect (for reviews see Bak & Alladi, 2014 and Guzman-Velez & Tranel, 2015). Additional languages increased the level of protection against dementia in a study conducted in Luxembourg (Perquin et al., 2013), socioeconomic and demographic factors restricted the protective effects to certain groups (Chertkow et al., 2010), interactions of education and degree of proficiency in both languages were associated with age of onset of AD (Gollan et al., 2011). Bilingualism, therefore, is only one factor in the complex set of activities, experiences, and biology that impact the expression of symptoms of neurodegenerative disease, but it is a factor that is consistent across a variety of contexts.

A different approach to investigating protective factors against dementia is through the use of incidence studies in which cohorts of healthy adults are followed over time to determine the rate of onset of dementia for those with various backgrounds or experiences. The idea is that experiences that substantially boost cognitive reserve will postpone symptoms or prevent disease onset, removing these individuals from the risk analyses that track incidence over time. A small number of incidence studies has investigated the role of bilingualism in defraying the likelihood of dementia but with few exceptions (e.g., Wilson et al., 2015), no significant effects have been found (Crane et al., 2009, 2010; Hack et al., 2012; Ljungberg, Hansson, Adolfsson, & Nilsson, 2016; Sanders, Hall, Katz, & Lipton, 2012; Zahodne, Schofield, Farrell, Stern, & Manly, 2014). However, the design and statistical structure of these studies needs to be considered carefully. First, only a small percentage of the original healthy cohort develops dementia, so the actual number of individuals that fall within each "protective" category is actually small. In the study by Ljungberg et al. (2016) the cohort began with 736 monolingual and 82 bilingual older adults who were followed for about 10 years. From this group, 112 participants developed dementia, including 102 monolinguals (about 14%) and 10 bilinguals (about 12%), but with so few bilinguals, the statistical analysis is inconclusive. In the study by Zahodne et al. (2014), from 1,067 participants, 282 (about 26%) developed dementia. Bilingualism was associated with better performance on cognitive measures, particularly those assessing executive function (cf., Bialystok et al., 2004), but cognitive decline in monolinguals and bilinguals was comparable (cf., Bialystok et al., 2014). Crucially, however, the model showed no statistical relation between bilingualism and dementia, even though there was a clear stratification of incidence of dementia as a function of four discrete levels of bilingualism (Zahodne et al., 2014, Figure 1), with greater bilingualism being associated with lower incidence of dementia and later onset of symptoms. The value of the difference between the levels of bilingualism was less than that found for age, education, and gender, all of which were included in the same statistical model. Thus, despite a clear disaggregation of incidence dementia of the 282 cases by language experience, there was insufficient power after accounting for the other factors to reveal a significant effect. Worrying as well is that monolinguals were defined as Spanish-speaking individuals who had lived in New York City for at least 30 years, a situation that is unlikely to be associated with pure monolingualism.

Similar problems are apparent in a study by Lawton, Gasquoine, and Weimer (2015) who studied a cohort of Hispanic individuals in California. From a sample of 1,789 individuals, 81 developed dementia, consisting of 54 monolingual and 27 bilingual patients. There were no significant differences in either the incidence or age of onset as a function of bilingualism or immigration status (about half the patients in each group were immigrants, although the exact numbers are not reported). However, the designation as monolingual or bilingual was based on two self-report questions, "Do you speak English" and "Do you speak Spanish," each of which was answered on a 4-point Likert scale. The two lower scores led to classification as "monolingual" and the two higher scores as "bilingual." The authors point out that over three-quarters of the monolinguals were Spanish speaking; given that they live in California it is unlikely that they speak no English at all, as in the Zahodne et al. (2014) sample. Moreover, only 27 of the participants designated as bilingual developed dementia. Numerically, this group was older (81 years) than the monolingual patients (79 years) but the difference was not statistically significant.

Another way of considering incidence is to use communities rather than individuals. Klein, Christie, and Parkvall (2016) examined the incidence of Alzheimer's disease in 93 countries that were rated in terms of the mean number of languages spoken by the population. They found a significant decline in the incidence of Alzheimer's disease with an increase in population multilingualism, a relation that became stronger when an estimate of life expectancy was included in the model. The results remained significant after controlling for the effects of such factors as wealth and literacy. These results are consistent with the interpretation of an overall protective effect of bilingualism.

From a clinical perspective, incidence studies are a purer measure of dementia risk than retrospective studies because of the contamination involved in determining when the disease actually appeared in retrospective studies. Yet, incidence studies rarely show a protective effect of bilingualism. How can this be reconciled with the positive evidence for cognitive reserve from retrospective studies? Part of the explanation is that the purpose of incidence studies is different from that of retrospective studies. In retrospective studies, the question is to determine the age or cognitive level at which individuals demonstrated symptoms of dementia or were given a formal clinical diagnosis. In incidence studies, the question is to determine the factors that serve to protect the individual so that the disease is avoided. It is well known that biological factors such as age modify the risk of dementia, and to that extent, they will impact the outcome of incidence studies. However, there is no evidence that bilingualism *prevents* dementia, only that it postpones symptoms and diagnoses. Yet, incidence studies that report no protection from bilingualism rarely report the age at which the bilinguals in the cohort were formally diagnosed with the disease; an exception is the study by Wilson et al. (2015) in which positive effects of bilingualism were in fact recorded. For this reason, we should not expect incidence studies to reveal protective effects of bilingualism.

A study by Schweizer et al. (2012) addresses this issue. The authors assessed 40 individuals who had been diagnosed with AD of whom 20 were monolingual and 20 were lifelong bilinguals, matched on age and results from a large cognitive and demographic battery, confirming that all patients in the two groups were functioning at similar cognitive levels. However, an analysis of brain atrophy showed significantly more deterioration in the medial temporal region, particularly hippocampus, for the bilinguals than the monolinguals, despite comparable behavioral measures. This region is the typical site of initial AD pathology, and the impact on the hippocampus is the reason for the characteristic memory failure. Yet, despite comparable behavioral performance, bilinguals had more disease burden than monolinguals but were able to perform at the same cognitive level as monolinguals. This dissociation between brain structure and cognitive level is the signature of cognitive reserve.

One study has extended this reasoning that bilingualism should provide protection against neurodegenerative disease to the case of stroke (Alladi et al., 2016). The prediction from cognitive reserve is different here than it is for dementia; there is no reason to expect bilingualism to prevent or postpone the occurrence of stroke, but the cognitive reserve imparted by bilingualism should contribute to poststroke recovery. The authors examined the records of 608 stroke patients in Hyderabad of whom 353 (58.1%) were bilingual. The age of stroke was identical in both language groups, around 56 years. Cognitive recovery after stroke depended on several factors: better outcomes were found for patients who were younger, more educated, had fewer vascular risk factors, and were bilingual. These factors were uncorrelated with each other, and a logistic regression showed that the factors that significantly predicted recovery were age and bilingualism. After therapy, 19.6% of monolingual patients showed normal cognitive function but 40.5% of bilingual patients achieved this outcome, about double the rate.

The evidence points to bilingualism as a means of postponing symptoms of dementia without avoiding the disease (Gold, 2016). However, if the disease is inevitable for reasons that are yet unknown, is there any value in delaying the symptoms? Alzheimer's disease is a disease of aging that has profoundly large social, personal, and economic costs. Keeping older adults functioning independently and in good health has immense benefit for individuals and societies. Brookmeyer, Johnson, Ziegler-Graham, and Arrighi (2007) used epidemiological data from 2006 to predict the prevalence of Alzheimer's disease in 2050 and projected that a 1 year delay in symptom onset translated into 9.2 million fewer cases of the disease. Wimo, Jonsson, and Winblad (2006) estimated that the worldwide direct costs of treating dementia, based on a 2003 prevalence estimate of 27.7 million patients, was $156 billion US dollars. Thus the savings that might be associated with a 1 year deferment in disease onset are impressive; the possibilities that follow from a 4 to 5 year deferment, as found for bilingualism, are staggering.

## The Mechanism of Neuroplasticity in Bilingualism

In the first reported study of better performance by bilingual children than monolinguals, Peal and Lambert (1962, p. 20) explain: "Intellectually his experience with two language systems seems to have left him with a mental flexibility, a superiority in concept formation, and a more diversified set of mental abilities, in the sense that the patterns of abilities developed by bilinguals were more heterogeneous." How could "experience with two language systems" lead to the reported cognitive outcomes? A first hint came from research with monolingual and bilingual children performing metalinguistic tasks. The studies followed from ideas introduced by Vygotsky (1962) in which he considered the ability to separate words and their meanings and see the relation between them as arbitrary to be an essential foundation for higher cognitive thought. Vygotsky's speculation was that experience with two languages in which meanings were paired with different symbols would lead children to that insight more quickly: "the child learns to see his language as one particular system among many, to view its phenomena under more general categories, and this leads to awareness of his linguistic operations" (Vygotsky, 1962, p. 110). In a series of studies conducted through the 1970s and 1980s, it became clear that it was precisely this separation of word and meaning that was more advanced in bilingual children (review in Bialystok, 2001). For example, children were asked to decide if a sentence was "said the right way" or not, and to ignore whether or not the sentence was "silly." There were four types of sentences: (a) grammatical meaningful sentences, (b) ungrammatical meaningful sentences, (c) grammatical silly sentences, and (d) ungrammatical silly sentences. The correct answer for (a) and (c) is "yes" and for (b) and (d) is "no," but meaning is more salient than form so there is a bias to say "no" for the (c) sentences. In several studies, monolingual and bilingual children performed equivalently on all conditions except (c), where bilingual children were more accurate (e.g., Bialystok, 1986, 1988; Cromdal, 1999). A similar pattern was later found with adults where the measure was not accuracy, for which everyone was at ceiling, but ERP showing a smaller P600 for bilinguals in the grammatical but silly sentences (Moreno, Bialystok, Wodniecka, & Alain, 2010). Because the sentences were in fact grammatically correct, a smaller P600 is appropriate. The P600 amplitude is heavily influenced by syntactic violations, with greater violations leading to enhanced P600 amplitudes (Friederici, Pfeifer, & Hahne, 1993). A compelling explanation for children's performance on these tasks in which they were required to ignore semantic information and focus on form was that the bilingual children were more able to "inhibit" attention to the meaning and "selectively attend" to the form.

## Inhibition and the Executive Function

The inhibition explanation was the leading account from early in this research. For example, the possibility that children were inhibiting the irrelevant meaning from the previous dimension was used to explain results from the Dimension Change Card Sort Task discussed in **Flexibility, Switching, and Monitoring of Attention in Children**. This interpretation was consistent with theoretical positions arguing that the development of inhibitory control was an essential basis of cognitive development (Dempster, 1992; Diamond, 1991). Fortifying this view, the inhibition explanation coincided with the appearance of Green's (1998) Inhibitory Control Model (**Mechanism for Bilingual Effects**) in which it was argued that bilingual language processing was based on an attention system, the Supervisory Attention System, that inhibited the unwanted language so that processing could proceed in the target language.

An important boost to the speculation that bilingualism enhanced inhibition came from the appearance of an influential model developed at the same time, namely, the unity and diversity model of executive function proposed by Miyake and colleagues (Miyake et al., 2000). The model was intended as a means of clarifying the structure of the executive function. The original study included 137 young adult participants who performed nine simple executive function tasks (three for each of the proposed three latent variables) and five complex executive function tasks to determine the relation between the latent variables and the complex tasks. Their analyses included factor analyses to determine the structure of the nine simple tasks and structural equation modeling to uncover the relation between the latent variables and performance on complex executive function tasks. The results revealed three core components that were moderately correlated with each other—shifting, updating (working memory), and inhibition—and contributed independently to performance on the five complex tasks. Although the overlap was acknowledged from the beginning, the main focus has been on the distinction among these three components. Specific tasks were proposed as measures of each component and performance on those tasks was considered to be an assessment of that subprocess. At some point, the associated tasks became proxies for the statistical construct of one of the components; the Stroop task was a measure of inhibition and the local-global task was a measure of shifting (see discussion in Kroll & Bialystok, 2013). Thus, converging evidence from cognitive development in childhood, language processing in bilinguals, and executive function in adults supported the interpretation that inhibition was central to understanding the effect of bilingualism on cognition.

Following from these models that were being proposed at the time, the hypothesis for the mechanism responsible for the effects of bilingualism on cognition was that experience in recruiting the frontal lobe to inhibit the unwanted language and allow processing to proceed through the target language had the long term effect of boosting inhibitory processes more broadly (Bialystok et al., 2009). Notably, the emerging interpretation up to that time was not based on inhibition but rather on "selective attention." For example, Bialystok (1992) argued that aspects of selective attention that were developing in childhood, such as those required to perform Piagetian conservation tasks, were more advanced in bilingual children because of their experience in attending to two languages. These notions of the importance of selective attention were largely replaced by explanations based on inhibition.

Work in understanding frontal lobe function that acknowledged it as the seat of the executive functions (Fuster, 2002) were also instrumental in focusing attention on the role of inhibition in bilingual cognitive performance. Three main sources of evidence made this explanation plausible. First, there was already substantial evidence that language selection was nonspecific in that both languages were jointly activated to some degree, therefore requiring a mechanism for language selection. This evidence for joint activation has increased in both quantity and sophistication in recent years (for review, Kroll et al., 2015). Second, the research with children showing better performance by bilingual than monolingual children on metalinguistic and cognitive tasks found group differences for conditions that required children to ignore salient but misleading information but not for comparable conditions that did not include distraction (for review, Bialystok, 2001). Because the assumption was that the bilingual effects on nonverbal cognitive performance were transferred from their experience in language selection, children under the age of about 4 years were not included in these studies because it was believed they had not yet accumulated sufficient language experience for such effects to be detected. Third, a new area of research, starting with Bialystok et al. (2004), investigated these hypotheses in adult populations using tasks similar to those reported by Miyake and colleagues in their study of the structure of executive function (e.g., Stroop as a measure of inhibition, task-switching as a measure of shifting) reported some evidence for better performance by bilinguals on these tasks. These results, however, were more precarious than those found for children and sometimes were not found for young adults (e.g., Bialystok et al., 2005a; Paap & Greenberg, 2013) or emerged only for the most complex conditions (e.g., Costa et al., 2009). All three types of evidence were consistent with the explanation based on enhanced inhibitory control, possibly as a consequence of experience in language inhibition, and endorsed the use of the Miyake framework as a means of understanding these effects.

The accumulation of empirical evidence and recent theorizing has cast doubt on all three sources of evidence outlined above for the inhibition interpretation. Consider first the assumption that the nontarget language is inhibited in bilingual language processing. There has been research for some time challenging the inhibition view in favor of one based on more effective selection of the target language. Research showing widespread facilitation and interference effects of the nontarget language on processing in the target language were found for such tasks as picture naming (e.g., Costa et al., 2000) and lexical decision (Bijeljac-babic, Biardeau, & Grainger, 1997; Duyck et al., 2007), making language inhibition unlikely. Costa et al. (2006) later proposed a hybrid account that included selection and inhibition, acknowledging a role for both but insisting that the influence of the nontarget language is never absent. At the very least, there is a deactivation of the nontarget language that reduces access (see, e.g., Linck, Kroll, & Sunderman, 2009), but the assumption that inhibition was the primary mechanism seems inaccurate.

Second, two developments in research with children further challenged the standard view. First, studies with children using tasks that required inhibition found different results if the inhibition were defined in terms of avoiding distraction (e.g., Stroop-type tasks) or refraining from executing a response (e.g., gift delay). In several studies, bilingual children outperformed monolingual children on the former but not the latter (e.g., Carlson & Meltzoff, 2008; Engel de Abreu et al., 2012; Foy & Mann, 2014; Martin-Rhee & Bialystok, 2008). Although these are different aspects of inhibition, they are not distinguished in the Miyake et al. (2000) model; stop-signal and Stroop tasks are considered equivalent in their contribution to the inhibition component.

The other development was the extension of this research to include preverbal toddlers and infants with only rudimentary control of comprehension and essentially no language production. In both cases, if cognitive differences from bilingualism could be detected, they could not be attributed to the experience of inhibiting the nontarget language. Yet, studies with children in the first year of life (Kovács & Mehler, 2009a) and preschool toddlers (Bialystok et al., 2010a) both found significant differences in the way in which monolingual and bilingual children performed nonverbal conflict tasks. Cognitive change is evident before productive language is established.

Third, the research with adults did not conform to the predictions from the explanatory framework based on the Miyake model in three crucial aspects. Given that the effect of bilingualism involved changes in executive function and frontal processing, studies using many of the tasks used by Miyake to demonstrate these constructs should have revealed differences between language groups but did not. Simple tasks, such as the flanker task, that are generally acknowledged to involve executive control were often performed equivalently by monolingual and bilingual young adults. Moreover, the inhibition hypothesis predicts that group differences will be found in incongruent trials that include distraction but not in congruent trials that do not. However, the majority of the studies that reported group differences on these tasks found them equally in both trial types (Hilchey & Klein, 2011), again challenging inhibition as a likely explanation. Finally, as Paap and colleagues frequently noted (e.g., Paap & Greenberg, 2013), there was little correlation across various executive function tasks. If executive function as specified in the Miyake model were the underlying mechanism, then the evidence should emerge on all these tasks, Miyake and colleagues (2000) reported in their original study that these intercorrelations were low, so it would be surprising if they became robust when applied to research on bilingualism. More importantly, recent work on this model has eliminated inhibition entirely as a source of unique variance (Miyake & Friedman, 2012). Overall, the inhibition model provides a poor fit to the patterns of results obtained from research on bilingualism.

## Finding the Pattern: Executive Attention

The explanation for the modification of brain and cognition from bilingual experience must ultimately be based on systems connected to executive function processes that are housed in frontal brain regions. Because definitions of executive function are typically vague, researchers working with these constructs have developed models that are quite different from each other. However, it is instructive to note that Baddeley's (1986) model of working memory included a central executive that moderated the function of the domain-specific slave systems through *attention*. This central executive bears striking resemblance to what others have called executive function. The difference is in the mechanism responsible for the "modulation" of cognitive operations.

Assigning a central role to attention, Engle and his colleagues have proposed the notion of working memory capacity as the combination of working memory and attention. Shipstead, Harrison, and Engle (2015, p. 1863) define working memory capacity as "the cognitive system in which memory and attention interact to produce complex cognition." More important, Engle (2002) suggests that this construct could equally be called "executive attention." Although both the Miyake and Engle approaches are attempts to explain a domain-general resource-limited monitoring system, there are two differences between them. First, unlike the compartmentalization of Miyake's unity or diversity view, Engle's working memory capacity is a continuous construct, making it more likely to show experience-dependent plasticity than would be found for a discrete construct. Second, working memory capacity is rooted in the deployment of attention, something missing from the unity/diversity view. The "capacity" referenced in working memory capacity is not storage space but rather the extent to which resources are available to control attention to maintain information relevant for a current task (Engle, 2002; Engle & Kane, 2004).

These two features make working memory capacity a construct that is compatible with the evidence found across the life span for bilingualism-dependent plasticity. The process that unites the results from infants, children, and adults is attention, and the measures at each stage of the life span are invariably assessments of attention to various kinds of representations. In the first year of life, infants in bilingual environments demonstrate better control over simple visual attention than infants in monolingual environments. Attention is at the core of the executive function tasks that both children and adult are asked to perform in this research. For language processing, the tension between inhibition and facilitation, as explained by Costa et al. (2006), is in their mutual reliance on attention. Something about bilingual environments or bilingual experience accelerates the development and maintenance of attention. Moreover, because it is conceptualized as a continuum rather than as a discrete process, it is easy to imagine a quantitative relation between the intensity of experience and nature of the outcomes; in a discrete componential model, different degrees or types of experience may lead to qualitatively different outcomes and would have difficulty accounting for the dose-related effects found in the literature (e.g., Bogulski, Rakoczy, Goodman, & Bialystok, 2015).

The responsiveness of working memory capacity to training has been tested in several studies by Engle and his colleagues. Harrison et al. (2013), for example, showed that intense training in working memory capacity, especially through the use of complex tasks rather than simple training tasks, improved performance on tasks described as near-transfer or moderate-transfer memory tasks. Their measure of far transfer was an assessment of fluid intelligence, but despite being correlated (Engle, Tuholski, Laughlin, & Conway, 1999), no amount of training led to increased scores on fluid intelligence tests. Although the extension from experience with language selection to nonverbal attention involving selection might be best considered as far-transfer, no claims have been made that bilingualism could increase fluid intelligence. The processes involved in modifying cognition for bilingualism, in contrast, are not considered to reflect transfer in which training in one task is applied to another task. Instead, the interpretation is that bilingualism involves an *adaptation* in which cognitive and brain systems used in both linguistic and nonlinguistic activities are modified as a consequence of being involved in those activities. In this sense, training through bilingual experience leads to an adaptation of cognitive and neural systems.

Regarding conceptualizations of attention, it is important to consider the influential model proposed by Posner and colleagues (e.g., Posner & Petersen, 1990). In this approach, the attention system is separate from other processing systems and is based on networks of brain regions. To this extent, the conceptualization is compatible with continuous models of executive attention like that proposed by Engle and relies on extensive brain areas. However, the approach also distinguishes among subsystems that are responsible for different functions, each depending primarily on different brain networks. The three primary attention networks identified in this research are sustained (parietal cortex, right frontal cortex), selective (parietal structures and frontal eye fields), and executive (left and right frontal cortex and ACC). To some extent, the executive attention subcomponent encompasses much of the processing generally included in current conceptions of executive function, such as working memory, set switching, and inhibitory control but without isolating them as in the Miyake model. Therefore, in addition to the obvious difference of focusing on attention rather than executive function, the model includes elements of both approaches described above.

As with the notion of working memory capacity, research based on an attention systems model has demonstrated the possibility of improving function through training. The strongest effects are found with the executive attention component, the construct most likely to be relevant to bilingual processing. Training studies with children have shown improved performance on such tasks as ANT after training on attention exercises, such as tracking, focusing, and selecting with conflict (Posner & Rothbart, 2005; Rueda, Checa, & Combita, 2012; Rueda, Posner, & Rothbart, 2005). Moreover, EEG analyses showed that the trained children activated the executive attention network more efficiently than untrained children, a difference that was maintained 2 months after training (Rueda et al., 2012).

Another hybrid approach that does not rely on standard interpretations of executive function focuses on conflict monitoring, a process based on control of attention. Botvinick, Braver, Barch, Carter, and Cohen (2001) proposed that the essence of cognitive control is the detection of conflict, and that this is achieved by the anterior cingulate cortex. Thus, constant monitoring of attention directed through the ACC becomes the basis for a model for executive control. This description is interesting in terms of bilingualism in which the jointly activated languages create constant conflict. The notion that the relevant mechanism for bilingual processing underlying performance on executive function tasks is monitoring has been proposed by both Costa et al. (2009) and Hilchey and Klein (2011), and the increased efficiency and structure of the ACC in bilinguals has also been reported (Abutalebi et al., 2012; Rodriguez-Pujadas et al., 2014). Notably, the ACC is also central to the Posner attention model (Fan et al., 2003). Monitoring of attention, specifically for the purpose of conflict detection, therefore, is compatible with behavioral and brain evidence from bilingualism research.

Attention is a plausible domain in which to search for a mechanism for the cognitive effects of bilingualism. A small number of studies have jointly investigated the effects of bilingualism and attention on performance in executive function tasks. Two studies have examined monolingual and bilingual young adults who did or did not have a clinical diagnosis of attention-deficit-hyperactivity disorder (ADHD; Bialystok et al., in press; Mor et al., 2015). In both studies, bilingual participants with ADHD showed significant deficits compared with the other groups, suggesting that an attention disorder not only prevents bilingualism from boosting performance but possibly also adds to the burden of the disorder (note, however, there were no monolinguals in the Mor et al., 2015 study). In contrast, a study by Sorge, Toplak, and Bialystok (2017) tested over 200 typically developing children between 8- and 11-years old and assigned a score to each child indicating the degree of bilingualism and the degree of attention ability. Unlike the studies by Mor et al. (2015) and Bialystok et al. (in press), none of the participants were clinically impaired but rather varied in their level of attentional control within the normal range. Higher bilingualism scores and better attention ability were both associated with better performance on three executive function tasks, with little interaction between them and no additional burden for their combination. In other words, both better attention and more bilingualism had similar outcomes. These results suggest some underlying commonality between processes involved in attention and processes affected by bilingualism. Crucially, these effects require that the attention system is intact, allowing bilingualism to influence performance. When the attention system is impaired as in clinical ADHD, the ongoing attention demands of bilingualism, presumably for language control, overburden the system.

The working hypothesis, therefore, is that lifelong bilingualism impacts a set of processes subsumed under the category of executive attention. Beginning in infancy, the attention system is adapted to the particular demands of a bilingual environment, and these adaptations become apparent in cognitive performance across the life span. The notion of executive attention incorporates elements from executive function models and from attention accounts, although no specific model is being endorsed here. Attention begins to develop at birth and evolves throughout childhood so it is well positioned to provide the basis for a set of findings that extend across the entire life span.

## Remaining Considerations

**Determining bilingualism.** Research based on individual differences is necessarily complex because of the myriad variables that distinguish among people, blurring the line between comparison groups. Bilingualism is particularly challenging in this respect because bilingualism itself is not one thing, making it difficult to use it as a categorical distinction among research participants (Luk & Bialystok, 2013). Some studies have taken different approaches to circumvent the problem of categorical assignments to groups. For example, bilingual experience can be used as a continuous variable to assign individuals a score for degree of bilingualism and these scores can be entered into multivariate designs to determine the relation among individual difference factors and outcomes (Bialystok & Barac, 2012; Sorge et al., 2017). Another approach is to compare high proficiency balanced bilinguals with lower proficiency bilinguals (Goral et al., 2015; Singh & Mishra, 2012, 2013; Weber, Johnson, Riccio, & Liew, 2016), again focusing on degree of bilingualism rather than its presence or absence. A similar approach is to compare simultaneous interpreters, a more demanding form of bilingualism, with balanced bilinguals (Becker et al., 2016; Hervais-Adelman, Moser-Mercer, & Golestani, 2015; Strobach et al., 2015). In all cases, participants who were more bilingual outperformed those who were less bilingual on both behavioral and brain outcomes. Therefore, even in the absence of evidence comparing groups of monolingual and bilingual participants, comparisons within bilingual participants reveal the continuous effects of experience. The calibration of the size of effect to the degree of bilingualism is consistent with experience-related plasticity.

The context of bilingualism may be as important as the degree or type of bilingualism. Green and Abutalebi (2013) address this issue in the "Adaptive Control Hypothesis." They identify three distinct interactional contexts and propose different consequences for each on eight control processes. These interactional contexts—single language, dual language, and dense code-switching—place different demands on brain and cognitive systems by requiring different degrees and types of language switching. This model provides a promising way for understanding the essential role of the environment in shaping cognitive systems. A few recent studies have provided support for these ideas (Hartanto & Yang, 2016; Yang, Hartanto, & Yang, 2016; Verreyt, Woumans, Vandelanotte, Szmalec, & Duyck, 2016), but final judgment on this model awaits further research.

**Relation between the languages.** Because the cognitive consequences of bilingualism are assumed to emerge from enhanced domain-general attention to jointly activated competing systems, it may be that the relation between these linguistic systems in terms of their degree of overlap modulates the effects. The evidence on this point is unclear, as cognitive consequences of bilingualism have been found with similar (Spanish–Catalan: Costa et al., 2008) and different (Korean–English: Yang & Yang, 2016) languages. Studies comparing speakers of dialects have shown inconsistent results; bidialectic children who spoke Cypriot Greek and standard Greek outperformed monolingual Greek-speaking children (Antoniou et al., 2016) but studies with adults reported no difference between Italian-Venetian bidialectics and monolingual Italian speakers (Scaltritti et al., 2017) or between Mandarin-Min bidialectics and monolingual Mandarin speakers (Wu, Zhang, & Guo, 2016). In contrast to these results, however, Abutalebi et al. (2015) investigated increases in grey matter density in the inferior parietal lobule in bilingual older adults and reported greater changes for bilinguals who spoke similar languages (Cantonese and Mandarin) than for those who spoke unrelated languages (Cantonese and English). More research is required to resolve this question.

**Demographic variables.** Returning to the problem of isolating individual differences, a number of potentially confounding factors have been proposed to challenge the interpretation that the reported cognitive effects can be attributed to bilingualism. Primary among these is socioeconomic status. Morton and Harper (2007) argued that socioeconomic status (SES) and not bilingualism was the relevant variable in early studies showing better performance by bilingual children on executive function tasks. They tested 34 children, half of whom were bilingual, and reported no group difference on a Simon task but a modest correlation between SES and executive function performance ($p < .05$). It is undeniable that SES affects these cognitive outcomes, but such results do not preclude effects from bilingualism as well. Several studies have examined SES in detail and found no evidence of confound with bilingualism in the cognitive outcomes. Studies in which SES is carefully controlled have shown that bilingual children (Blom et al., 2014; Engel de Abreu et al., 2012; Kang, Thoemmes, & Lust, 2016) and adults (Nair, Biedermann, & Nickels, in press) outperform monolinguals at both low levels of SES and high levels of SES (Morales et al., 2013: Yang et al., 2011). For example, Engel de Abreu et al. (2012) reported a study with 8-year-olds in which both monolingual and bilingual children were from very low socioeconomic backgrounds and again, bilingual children outperformed monolinguals on this task. Similarly, Mezzacappa (2004) studied 6-year olds with a range of backgrounds and found faster performance on the ANT by bilinguals than monolinguals and by children with high socioeconomic status than children with lower socioeconomic status. Those studies examined performance within a specific socioeconomic range, but research that has simultaneously examined both bilingualism and SES has found independent effects for both (Calvo & Bialystok, 2014; Krizman, Skoe, & Kraus, 2016.

Similar arguments have been made about immigration being confounded with bilingualism. Fuller-Thomas and colleagues (Fuller-Thomson, 2015; Fuller-Thomson, Milaszewski, & Abdelmessih, 2013) citing the "healthy immigrant" phenomenon in which immigration selects for individuals who are more likely to succeed under challenging situations. Because many bilinguals are also immigrants, their argument is that the cognitive effects are a consequence of immigration and not bilingualism. However, the predictions from this view are not supported by analyses that divide the sample according to immigration status (Schweizer, Craik, & Bialystok, 2013) nor by close examination of the logic of the argument and the existing data (Bak, 2015; Bak & Alladi, 2016). More broadly, effects of bilingualism found in countries where bilingualism is not associated with immigration, such as India (Alladi et al., 2013) and Spain (Costa et al., 2008) are equivalent in nature and degree to effects found in countries where bilinguals are more likely to be immigrants.

Culture may be another such factor. In a study by Yang and Yang (2016) using the flanker task, monolingual children in Korea attained higher accuracy than monolingual children in the United States. Nonetheless, the Korean–English bilinguals outperformed both these groups, so whatever the effect of culture it did not replace the effect of bilingualism. Similarly, Tran, Arredondo, and Yoshida (2015) administered the children's ANT to 3-year-olds children from three countries (United States, Argentina, and Vietnam) who were monolingual and bilingual and found that both bilingualism and certain cultures were associated with better performance: bilinguals outperformed monolinguals and Eastern children outperformed Western children irrespective of bilingualism.

Finally, Hernandez and colleagues have proposed that alleles of the DRD2 gene are differentially distributed among monolingual and bilingual populations and that this difference is responsible for some performance difference between monolinguals and bilinguals (Hernandez, Greene, Vaughn, Francis, & Grigorenko, 2015; Vaughn et al., 2016). Their rationale is that the gene is important in dopamine availability, and this in turn affects cognitive control. As with the individual difference variables described above, their studies show effects of both genetic structure and bilingualism on executive function performance. More research is necessary before these effects can be understood.

**The problem of causality.** The research comparing monolingual and bilingual groups of participants is essentially correlational—a randomized control trial for a life experience would be an astonishing idea—so interpretations of causality are largely inferential. There are, however, alternative means of establishing the causal role of bilingualism in the results. One method is through training studies: language training studies using pretest/posttest designs have shown post training improvement on executive function tasks for children (Janus, Lee, Moreno, & Bialystok, 2016), and adults (Bak et al., 2016; Sullivan et al., 2014) in the trained group but not in the control group. The use of random or quasi-random assignment to training groups and demonstration of equivalent performance across groups before training allows posttraining results to be interpreted causally.

A second approach is to examine participants in the process of becoming bilingual. Bialystok and Barac (2012) tested children who were learning a second language in immersion programs on executive function tasks. Children who had been in the programs longer and were more bilingual performed better on these tasks, over and above all other factors. Their increasing skill in these tasks was tied to their level of bilingualism.

Finally, a study by Bak, Nissan, Allerhand, and Deary (2014) presented evidence that amounts to a 60-year longitudinal study. Children in Scotland were given extensive intelligence tests in 1947 at age 11 and then retested over 60 years later. For those who remained monolingual, their intelligence results at age 11 predicted their intelligence results at age 72, an outcome reflecting the reliability of intelligence tests. The dramatic finding was that those who became actively bilingual during their lives, after age 11, produced intelligence scores that were significantly higher than those predicted by their childhood results. Models that controlled for a variety of extraneous variables all led to the conclusion that the enhanced performance was related to their adult bilingual experience.

## Implications for Experience-Dependent Plasticity

It is now widely accepted that experience has the power to affect cognitive outcomes and brain structure and function throughout the life span. Some examples of these experiences, listed in **Bilingualism as a Context for Neuroplasticity**, include the effects of musical training, formal education, and high SES. However, the relation between the experience and the consequent modification of brain or cognitive systems is not simple and it is not unidimensional. Consider the example of hippocampal changes as a function of spatial experience. Maguire et al. (2000) reported an increase in hippocampal volume for London taxi drivers compared to nontaxi driver controls in the posterior regions of the hippocampus but a significant decrease in volume in the anterior hippocampus. The authors interpret these findings in terms of redistribution of grey matter density through the hippocampus, a process that is inherently more complex than fortification of one region through experience. Put another way, the reorganization was more extensive and more complex than could be explained by a single factor or a single outcome.

In addition to a multifaceted relation between experience and outcomes, the mechanism for those effects is rarely specified. There are well-documented example of the effects of SES on cognitive and brain outcomes, including executive function development (Noble, McCandliss, & Farah, 2007), and the effects of these early environments extend beyond cognitive function to include long-term outcomes for achievement, wealth, and health (Duncan, Ziol-Guest, & Kalil, 2010). Socioeconomic factors have also been related to cognitive level as measured by executive function, nonverbal intelligence, and decision making in adulthood (Mani, Mullainathan, Shafir, & Zhao, 2013). These results linking SES to later outcomes are reliable and have been widely reproduced, although even here there are studies that fail to find significant effects (Waber et al., 2007; Wiebe, Espy, & Charak, 2008). However, what is the mechanism by which SES creates these effects on brain and cognitive systems?

Details of the mechanism by which SES modifies cognitive ability are less clear than is the evidence for their effects. Compelling arguments have been proposed for the role of health, nutrition, prenatal factors, cognitive stimulation, and stress that are correlated with SES, and all are undoubtedly relevant (Hackman, Farah, & Meaney, 2010; Noble, Norman, & Farah, 2005). An interesting speculation on the mechanism responsible for the effects of SES on adult cognition is that poverty has the effect of limiting attentional range, making individuals more susceptible to "capture," and reducing the resources needed to deploy attention effectively and flexibly (Shah, Mullainathan, & Shafir, 2012). This description provides a counterpoint to the argument for bilingualism where the experience of selecting between multiple languages is claimed to *increase* attentional range and flexibility and therefore reduce the susceptibility to capture. Again, detailed studies on the impact of experience on attention appear to be a fruitful avenue of research; as in research on bilingualism, attentional control appears to be a crucial underlying difference between high and low SES groups (Stevens, Lauinger, & Neville, 2009). Yet, the absence of a precise mechanism by which SES affects cognitive development has not undermined the research and conclusions regarding the effects of SES. Nor should it undermine or impede research into the effects of bilingualism.

Finally, not all studies investigating the potential consequences of bilingualism on brain and behaviors have produced significant findings, a point that has received considerable attention. There are two issues to consider in this regard. First, studies that have failed to find differences between monolingual and bilingual groups have instead found no differences, that is, null results, but are interpreted as negative results. However, absence of evidence is not evidence of absence (see discussion in Bialystok, 2016) and the nature of hypothesis testing is that not every study will produce the same result. The interpretation of this variability is at the foundation of inferential statistics, the primary method for research in the social sciences. For example, two large-scale studies of receptive vocabulary each included almost 2,000 participants by combining data from a large number of individual studies. Because the vocabulary measure, the Peabody Picture Vocabulary test, is a standardized test, results can be compared across studies. The results showed that the distribution of scores were normal for both language groups but that monolinguals had significantly higher vocabulary scores than bilinguals for in both children (Bialystok, Luk, Peets, & Yang, 2010b) and adults (Bialystok & Luk, 2012). Even though individual studies sometimes showed no difference between groups, the shift of the normal distribution indicating a difference between means in the larger sample was clear. Similarly, on average, studies show that bilinguals outperform monolinguals on some cognitive tasks. Specific studies that come from the overlapping portion of the curves do not refute the pattern.

Second, research results need to be evaluated in terms of the quality of the study, and not all studies are equally sound. The two main issues in research on bilingualism are the validity of the designation for individuals in language groups and the validity of the task as a measure of a cognitive outcome likely to be impacted by bilingualism. As noted in **Remaining Considerations**, bilingualism is not a categorical variable (Luk & Bialystok, 2013), so comparisons between groups that are not in fact monolingual and bilingual will produce noise or null results (see discussion in Bialystok, 2016). Similarly, not all tasks recruit processes that are expected to be impacted by bilingualism, so studies need to explain the relation between the task and a conception of bilingual processing. Increasingly, studies are reported showing no differences between monolingual and bilingual participants on tasks for which there is no reason to expect any. For example, Kalia et al. (2014) found no differences in a task requiring participants to associate numerals with key presses, a task that was achieved to at least 96% accuracy by all participants. There is nothing in this task that can be expected to capture aspects of processing affected by bilingualism. An approach based on theoretically motivated hypotheses is required to evaluate the hypothesis that bilingualism is associated with modifications in cognitive function.

Experience has the power to modify cognitive and brain systems, and of all the experiences in which we engage, the way we use language must be among the most intense and the most profound. It is perhaps not surprising that bilingualism changes the way language processing is carried out; it is certainly less expected that it also changes the way that nonverbal cognitive processing is conducted. Nothing is as complex as the human mind, and investigations of the myriad factors that shape human cognition cannot be reduced to single-factor models that erase the inherent complexity of the question as an expedient to arrive at a simple answer. Understanding how bilingualism produces changes in mind and brain requires integrating evidence from across the life span from infancy, to old age, including patient studies, using techniques that assess brain and behavior in all their manifestations. Although not easy, carrying out this exercise leads to the conclusion that there is coherent evidence that bilingual minds adapt to their unique situation and that the adaptation has consequences for mind and brain. Much remains unknown but that does not overrule what *is* known.

## References

Abutalebi, J., Canini, M., Della Rosa, P. A., Green, D. W., & Weekes, B. S. (2015). The neuroprotective effects of bilingualism upon the inferior parietal lobule: A structural neuroimaging study in aging Chinese bilinguals. *Journal of Neurolinguistics, 33,* 3–13. http://dx.doi.org/10.1016/j.jneuroling.2014.09.008

Abutalebi, J., Canini, M., Della Rosa, P. A., Sheung, L. P., Green, D. W., & Weekes, B. S. (2014). Bilingualism protects anterior temporal lobe integrity in aging. *Neurobiology of Aging, 35,* 2126–2133. http://dx.doi.org/10.1016/j.neurobiolaging.2014.03.010

Abutalebi, J., Della Rosa, P. A., Green, D. W., Hernandez, M., Scifo, P., Keim, R., . . . Costa, A. (2012). Bilingualism tunes the anterior cingulate cortex for conflict monitoring. *Cerebral Cortex, 22,* 2076–2086. http://dx.doi.org/10.1093/cercor/bhr287

Abutalebi, J., & Green, D. W. (2007). Bilingual language production: The neurocognition of language representation and control. *Journal of Neurolinguistics, 20,* 242–275. http://dx.doi.org/10.1016/j.jneuroling.2006.10.003

Adesope, O. O., Lavin, T., Thompson, T., & Ungerleider, C. (2010). A systematic review and meta-analysis of the cognitive correlates of bilingualism. *Review of Educational Research, 80,* 207–245. http://dx.doi.org/10.3102/0034654310368803

Adi-Japha, E., Berberich-Artzi, J., & Libnawi, A. (2010). Cognitive flexibility in drawings of bilingual children. *Child Development, 81,* 1356–1366. http://dx.doi.org/10.1111/j.1467-8624.2010.01477.x

Alladi, S., Bak, T. H., Duggirala, V., Surampudi, B., Shailaja, M., Shukla, A. K., . . . Kaul, S. (2013). Bilingualism delays age at onset of dementia, independent of education and immigration status. *Neurology, 81,* 1938–1944. http://dx.doi.org/10.1212/01.wnl.0000436620.33155.a4

Alladi, S., Bak, T. H., Mekala, S., Rajan, A., Chaudhuri, J. R., Mioshi, E., . . . Kaul, S. (2016). Impact of bilingualism on cognitive outcome after stroke. *Stroke, 47,* 258–261. http://dx.doi.org/10.1161/STROKEAHA.115.010418

Antón, E., Duñabeitia, J. A., Estévez, A., Hernández, J. A., Castillo, A., Fuentes, L. J., . . . Carreiras, M. (2014). Is there a bilingual advantage in the ANT task? Evidence from children. *Frontiers in Psychology, 5,* 398.

Antón, E., Fernández García, Y., Carreiras, M., & Dunabeitia, J. A. (2016). Does bilingualism shape inhibitory control in the elderly? *Journal of Memory and Language, 90,* 147–160. http://dx.doi.org/10.1016/j.jml.2016.04.007

Antoniou, K., Grohmann, K. K., Kambanaros, M., & Katsos, N. (2016). The effect of childhood bilectalism and multilingualism on executive control. *Cognition, 149,* 18–30. http://dx.doi.org/10.1016/j.cognition.2015.12.002

Arredondo, M. M., Hu, X. S., Satterfield, T., & Kovelman, I. (2016). Bilingualism alters children's frontal lobe functioning for attentional control. *Developmental Science*. [Advance online publication.]

Ayneto, A., & Sebastian-Galles, N. (2017). The influence of bilingualism on the preference for the mouth region of dynamic faces. *Developmental Science, 20*. e12446. http://dx.doi.org/10.1111/desc.12446

Baddeley, A. D. (1986). *Working memory*. New York, NY: Oxford University Press.

Bak, T. H. (2015). Beyond a simple "yes" and "no." *Cortex, 73,* 332–333. http://dx.doi.org/10.1016/j.cortex.2015.08.003

Bak, T. H. (2016). The impact of bilingualism on cognitive aging and dementia: Finding a path through a forest of confounding variables. *Linguistic Approaches to Bilingualism, 6,* 205–226. http://dx.doi.org/10.1075/lab.15002.bak

Bak, T. H., & Alladi, S. (2014). Can being bilingual affect the onset of dementia? *Future Neurology, 9,* 101–103. http://dx.doi.org/10.2217/fnl.14.8

Bak, T. H., & Alladi, S. (2016). Bilingualism, dementia and the tale of many variables: Why we need to move beyond the Western World. Commentary on Lawton et al. (2015) and Fuller-Thomson (2015). *Cortex, 74,* 315–317. http://dx.doi.org/10.1016/j.cortex.2015.04.025

Bak, T. H., Long, M. R., Vega-Mendoza, M., & Sorace, A. (2016). Novelty, challenge, and practice: The impact of intensive language learning on attentional functions. *PLoS ONE, 11,* e0153485. http://dx.doi.org/10.1371/journal.pone.0153485

Bak, T. H., Nissan, J. J., Allerhand, M. M., & Deary, I. J. (2014). Does bilingualism influence cognitive aging? *Annals of Neurology, 75,* 959–963. http://dx.doi.org/10.1002/ana.24158

Barac, R., Bialystok, E., Castro, D. C., & Sanchez, M. (2014). The cognitive development of young dual language learners: A critical review. *Early Childhood Research Quarterly, 29,* 699–714. http://dx.doi.org/10.1016/j.ecresq.2014.02.003

Barac, R., Moreno, S., & Bialystok, E. (2016). Behavioral and electrophysiological differences in executive control between monolingual and bilingual children. *Child Development, 87,* 1277–1290. http://dx.doi.org/10.1111/cdev.12538

Bavelier, D., & Davidson, R. J. (2013). Brain training: Games to do you good. *Nature, 494,* 425–426. http://dx.doi.org/10.1038/494425a

Becker, M., Schubert, T., Strobach, T., Gallinat, J., & Kühn, S. (2016). Simultaneous interpreters vs. professional multilingual controls: Group differences in cognitive control as well as brain structure and function. *NeuroImage, 134,* 250–260. http://dx.doi.org/10.1016/j.neuroimage.2016.03.079

Becker, T. M., Prat, C. S., & Stocco, A. (2016). A network-level analysis of cognitive flexibility reveals a differential influence of the anterior cingulate cortex in bilinguals versus monolinguals. *Neuropsychologia, 85,* 62–73. http://dx.doi.org/10.1016/j.neuropsychologia.2016.01.020

Bennett, D. A., Wilson, R. S., Schneider, J. A., Evans, D. A., Mendes de Leon, C. F., Arnold, S. E., . . . Bienias, J. L. (2003). Education modifies the relation of AD pathology to level of cognitive function in older persons. *Neurology, 60,* 1909–1915. http://dx.doi.org/10.1212/01.WNL.0000069923.64550.9F

Berken, J. A., Chai, X., Chen, J. K., Gracco, V. L., & Klein, D. (2016). Effects of early and late bilingualism on resting-state functional connectivity. *The Journal of Neuroscience, 36,* 1165–1172. http://dx.doi.org/10.1523/JNEUROSCI.1960-15.2016

Bialystok, E. (1986). Factors in the growth of linguistic awareness. *Child Development, 57,* 498–510. http://dx.doi.org/10.2307/1130604

Bialystok, E. (1988). Levels of bilingualism and levels of linguistic awareness. *Developmental Psychology, 24,* 560–567. http://dx.doi.org/10.1037/0012-1649.24.4.560

Bialystok, E. (1992). Selective attention in cognitive processing: The bilingual edge. In R. J. Harris (Ed.), *Cognitive processing in bilinguals* (pp. 501–513). Amsterdam: North-Holland. http://dx.doi.org/10.1016/S0166-4115(08)61513-7

Bialystok, E. (1999). Cognitive complexity and attentional control in the bilingual mind. *Child Development, 70,* 636–644. http://dx.doi.org/10.1111/1467-8624.00046

Bialystok, E. (2001). *Bilingualism in development: Language, literacy, and cognition*. New York, NY: Cambridge University Press. http://dx.doi.org/10.1017/CBO9780511605963

Bialystok, E. (2016). The signal and the noise: Finding the pattern in human behavior. *Linguistic Approaches to Bilingualism, 6,* 517–534.

Bialystok, E., & Barac, R. (2012). Emerging bilingualism: Dissociating advantages for metalinguistic awareness and executive control. *Cognition, 122,* 67–73. http://dx.doi.org/10.1016/j.cognition.2011.08.003

Bialystok, E., Barac, R., Blaye, A., & Poulin-Dubois, D. (2010a). Word mapping and executive functioning in young monolingual and bilingual children. *Journal of Cognition and Development, 11,* 485–508. http://dx.doi.org/10.1080/15248372.2010.516420

Bialystok, E., Craik, F. I. M., Binns, M. A., Ossher, L., & Freedman, M. (2014). Effects of bilingualism on the age of onset and progression of MCI and AD: Evidence from executive function tests. *Neuropsychology, 28,* 290–304. http://dx.doi.org/10.1037/neu0000023

Bialystok, E., Craik, F. I. M., & Freedman, M. (2007). Bilingualism as a protection against the onset of symptoms of dementia. *Neuropsychologia, 45,* 459–464. http://dx.doi.org/10.1016/j.neuropsychologia.2006.10.009

Bialystok, E., Craik, F. I. M., Grady, C., Chau, W., Ishii, R., Gunji, A., & Pantev, C. (2005b). Effect of bilingualism on cognitive control in the Simon task: Evidence from MEG. *NeuroImage, 24,* 40–49. http://dx.doi.org/10.1016/j.neuroimage.2004.09.044

Bialystok, E., Craik, F. I. M., Green, D. W., & Gollan, T. H. (2009). Bilingual Minds. *Psychological Science in the Public Interest, 10,* 89–129. http://dx.doi.org/10.1177/1529100610387084

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. http://dx.doi.org/10.1037/0882-7974.19.2.290

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

Bialystok, E., Craik, F. I. M., & Ryan, J. (2006). Executive control in a modified antisaccade task: Effects of aging and bilingualism. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 32,* 1341–1354. http://dx.doi.org/10.1037/0278-7393.32.6.1341

Bialystok, E., Hawrylewicz, K., Wiseheart, M., & Toplak, M. (in press). Interaction of bilingualism and Attention-Deficit/Hyperactivity disorder in young adults. *Bilingualism: Language and Cognition*. [Advance online publication.]

Bialystok, E., & Luk, G. (2012). Receptive vocabulary differences in monolingual and bilingual adults. *Bilingualism: Language and Cognition, 15,* 397–401.

Bialystok, E., Luk, G., Peets, K. F., & Yang, S. (2010b). Receptive vocabulary differences in monolingual and bilingual children. *Bilingualism: Language and Cognition, 13,* 525–531. http://dx.doi.org/10.1017/S1366728909990423

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. http://dx.doi.org/10.1111/j.1467-7687.2004.00351.x

Bialystok, E., Martin, M. M., & Viswanathan, M. (2005a). Bilingualism across the lifespan: The rise and fall of inhibitory control. *The International Journal of Bilingualism, 9,* 103–119. http://dx.doi.org/10.1177/13670069050090010701

Bialystok, E., Poarch, G., Luo, L., & Craik, F. I. M. (2014). Effects of bilingualism and aging on executive function and working memory. *Psychology and Aging, 29,* 696–705. http://dx.doi.org/10.1037/a0037254

Bialystok, E., & Senman, L. (2004). Executive processes in appearance-reality tasks: The role of inhibition of attention and symbolic representation. *Child Development, 75,* 562–579. http://dx.doi.org/10.1111/j.1467-8624.2004.00693.x

Bialystok, E., & Shapero, D. (2005). Ambiguous benefits: The effect of bilingualism on reversing ambiguous figures. *Developmental Science, 8,* 595–604. http://dx.doi.org/10.1111/j.1467-7687.2005.00451.x

Bialystok, E., & Viswanathan, M. (2009). Components of executive control with advantages for bilingual children in two cultures. *Cognition, 112,* 494–500. http://dx.doi.org/10.1016/j.cognition.2009.06.014

Bijeljac-babic, R., Biardeau, A., & Grainger, J. (1997). Masked orthographic priming in bilingual word recognition. *Memory & Cognition, 25,* 447–457. http://dx.doi.org/10.3758/BF03201121

Blom, E., Küntay, A. C., Messer, M., Verhagen, J., & Leseman, P. (2014). The benefits of being bilingual: Working memory in bilingual Turkish-Dutch children. *Journal of Experimental Child Psychology, 128,* 105–119. http://dx.doi.org/10.1016/j.jecp.2014.06.007

Blumenfeld, H. K., & Marian, V. (2011). Bilingualism influences inhibitory control in auditory comprehension. *Cognition, 118,* 245–257. http://dx.doi.org/10.1016/j.cognition.2010.10.012

Blumenfeld, H. K., & Marian, V. (2014). Cognitive control in bilinguals: Advantages in Stimulus-Stimulus inhibition. *Bilingualism: Language and Cognition, 17,* 610–629. http://dx.doi.org/10.1017/S1366728913000564

Bogulski, C. A., Rakoczy, M., Goodman, M., & Bialystok, E. (2015). Executive control in fluent and lapsed bilinguals. *Bilingualism: Language and Cognition, 18,* 561–567. http://dx.doi.org/10.1017/S1366728914000856

Bonifacci, P., Giombini, L., Bellocchi, S., & Contento, S. (2011). Speed of processing, anticipation, inhibition and working memory in bilinguals. *Developmental Science, 14,* 256–269. http://dx.doi.org/10.1111/j.1467-7687.2010.00974.x

Botvinick, M. M., Braver, T. S., Barch, D. M., Carter, C. S., & Cohen, J. D. (2001). Conflict monitoring and cognitive control. *Psychological Review, 108,* 624–652. http://dx.doi.org/10.1037/0033-295X.108.3.624

Braver, T. S., Barch, D. M., Keys, B. A., Carter, C. S., Cohen, J., Kaye, J. A., . . . Reed, B. R. (2001). Context processing in older adults: Evidence for a theory relating cognitive control to neurobiology in healthy aging. *Journal of Experimental Psychology: General, 130,* 746–763.

Brito, N., & Barr, R. (2012). Influence of bilingualism on memory generalization during infancy. *Developmental Science, 15,* 812–816. http://dx.doi.org/10.1111/j.1467-7687.2012.1184.x

Brito, N., & Barr, R. (2014). Flexible memory retrieval in bilingual 6-month-old infants. *Developmental Psychobiology, 56,* 1156–1163. http://dx.doi.org/10.1002/dev.21188

Brito, N. H., Grenell, A., & Barr, R. (2014). Specificity of the bilingual advantage for memory: Examining cued recall, generalization, and working memory in monolingual, bilingual, and trilingual toddlers. *Frontiers in Psychology, 5,* 1369. http://dx.doi.org/10.3389/fpsyg.2014.01369

Brito, N. H., Sebastian-Galles, N., & Barr, R. (2015). Differences in language exposure and its effects on memory flexibility in monolingual, bilingual, and trilingual infants. *Bilingualism: Language and Cognition, 18,* 670–682. http://dx.doi.org/10.1017/S1366728914000789

Brookmeyer, R., Johnson, E., Ziegler-Graham, K., & Arrighi, H. M. (2007). Forecasting the global burden of Alzheimer's disease. *Alzheimer's & Dementia, 3,* 186–191. http://dx.doi.org/10.1016/j.jalz.2007.04.381

Buchsbaum, B. R., Olsen, R. K., Koch, P., & Berman, K. F. (2005). Human dorsal and ventral auditory streams subserve rehearsal-based and echoic processes during verbal working memory. *Neuron, 48,* 687–697. http://dx.doi.org/10.1016/j.neuron.2005.09.029

Calabria, M., Hernández, M., Martin, C. D., & Costa, A. (2011). When the tail counts: The advantage of bilingualism through the ex-gaussian distribution analysis. *Frontiers in Psychology, 2,* 250. http://dx.doi.org/10.3389/fpsyg.2011.00250

Calvo, A., & Bialystok, E. (2014). Independent effects of bilingualism and socioeconomic status on language ability and executive functioning. *Cognition, 130,* 278–288. http://dx.doi.org/10.1016/j.cognition.2013.11.015

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

Chertkow, H., Whitehead, V., Phillips, N., Wolfson, C., Atherton, J., & Bergman, H. (2010). Multilingualism (but not always bilingualism) delays the onset of Alzheimer disease: Evidence from a bilingual community. *Alzheimer Disease and Associated Disorders, 24,* 118–125. http://dx.doi.org/10.1097/WAD.0b013e3181ca1221

Chung-Fat-Yim, A., Sorge, G. B., & Bialystok, E. (2017). The relationship between bilingualism and selective attention in young adults: Evidence from an ambiguous figures task. *The Quarterly Journal of Experimental Psychology, 70,* 366–372.

Coderre, E. L., Van Heuven, W. J. B., & Conklin, K. (2013). The timing and magnitude of Stroop interference and facilitation in monolinguals and bilinguals. *Bilingualism: Language and Cognition, 16,* 420–441. http://dx.doi.org/10.1017/S1366728912000405

Colcombe, S., & Kramer, A. F. (2003). Fitness effects on the cognitive function of older adults: A meta-analytic study. *Psychological Science, 14,* 125–130. http://dx.doi.org/10.1111/1467-9280.t01-1-01430

Colzato, L. S., Bajo, M. T., van den Wildenberg, W., Paolieri, D., Nieuwenhuis, S. L. A., Heij, W., & Hommel, B. (2008). How does bilingualism improve executive control? A comparison of active and reactive inhibition mechanisms. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 34,* 302–312. http://dx.doi.org/10.1037/0278-7393.34.2.302

Costa, A., Caramazza, A., & Sebastian-Galles, N. (2000). The cognate facilitation effect: Implications for models of lexical access. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 26,* 1283–1296. http://dx.doi.org/10.1037/O278-7393.26.5.1283

Costa, A., Hernández, M., Costa-Faidella, J., & Sebastián-Gallés, N. (2009). On the bilingual advantage in conflict processing: Now you see it, now you don't. *Cognition, 113,* 135–149. http://dx.doi.org/10.1016/j.cognition.2009.08.001

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

Costa, A., Santesteban, M., & Ivanova, I. (2006). How do highly proficient bilinguals control their lexicalization process? Inhibitory and language-specific selection mechanisms are both functional. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 32,* 1057–1074. http://dx.doi.org/10.1037/0278-7393.32.5.1057

Costumero, V., Rodríguez-Pujadas, A., Fuentes-Claramonte, P., & Ávila, C. (2015). How bilingualism shapes the functional architecture of the brain: A study on executive control in early bilinguals and monolinguals. *Human Brain Mapping, 36,* 5101–5112. [Advance online publication.] http://dx.doi.org/10.1002/hbm.22996

Craik, F. I. M., Bialystok, E., & Freedman, M. (2010). Delaying the onset of Alzheimer disease: Bilingualism as a form of cognitive reserve. *Neurology, 75,* 1726–1729. http://dx.doi.org/10.1212/WNL.0b013e3181fc2a1c

Crane, P. K., Gibbons, L. E., Arani, K., Nguyen, V., Rhoads, K., McCurry, S. M., . . . White, L. (2009). Midlife use of written Japanese and protection from late life dementia. *Epidemiology, 20,* 766–774. http://dx.doi.org/10.1097/EDE.0b013e3181b09332

Crane, P. K., Gruhl, J. C., Erosheva, E. A., Gibbons, L. E., McCurry, S. M., Rhoads, K., . . . White, L. (2010). Use of spoken and written Japanese did not protect Japanese-American men from cognitive decline in late life. *The Journals of Gerontology, Series B: Psychological Sciences and Social Sciences, 65B,* 654–666. http://dx.doi.org/10.1093/geronb/gbq046

Crivello, C., Kuzyk, O., Rodrigues, M., Friend, M., Zesiger, P., & Poulin-Dubois, D. (2016). The effects of bilingual growth on toddlers' executive function. *Journal of Experimental Child Psychology, 141,* 121–132. http://dx.doi.org/10.1016/j.jecp.2015.08.004

Cromdal, J. (1999). Childhood bilingualism and metalinguistic skills: Analysis and control in young Swedish-English bilinguals. *Applied Psycholinguistics, 20,* 1–20. http://dx.doi.org/10.1017/S0142716499001010

De Baene, W., Duyck, W., Brass, M., & Carreiras, M. (2015). Brain circuit for cognitive control is shared by task and language switching. *Journal of Cognitive Neuroscience, 27,* 1752–1765. http://dx.doi.org/10.1162/jocn_a_00817

de Bruin, A., Bak, T. H., & Della Sala, S. (2015). Examining the effects of active versus inactive bilingualism on executive control in a carefully matched non-immigrant sample. *Journal of Memory and Language, 85,* 15–26. http://dx.doi.org/10.1016/j.jml.2015.07.001

Della Rosa, P. A., Videsott, G., Borsa, V. M., Canini, M., Weekes, B. S., Franceschini, R., & Abutalebi, J. (2013). A neural interactive location for multilingual talent. *Cortex, 49,* 605–608. http://dx.doi.org/10.1016/j.cortex.2012.12.001

Dempster, F. N. (1992). The rise and fall of the inhibitory mechanism: Toward a unified theory of cognitive development and aging. *Developmental Review, 12,* 45–75. http://dx.doi.org/10.1016/0273-2297(92)90003-K

Dennis, N. A., & Cabeza, R. (2011). Age-related dedifferentiation of learning systems: An fMRI study of implicit and explicit learning. *Neurobiology of Aging, 32,* 2318 e2317–2330. http://dx.doi.org/10.1016/j.neurobiolaging.2010.04.004

Diamond, A. (1991). Neuropsychological insights into the meaning of object concept development. In S. Carey & R. Gelman (Eds.), *The epigenesis of mind: Essays on biology and cognition* (pp. 67–110). Hillsdale, NJ: Erlbaum.

Dijkstra, T., Grainger, J., & van Heuven, W. J. B. (1999). Recognition of cognates and interlingual homographs: The neglected role of phonology. *Journal of Memory and Language, 41,* 496–518. http://dx.doi.org/10.1006/jmla.1999.2654

Draganski, B., Gaser, C., Busch, V., Schuierer, G., Bogdahn, U., & May, A. (2004). Neuroplasticity: Changes in grey matter induced by training. *Nature, 427,* 311–312. http://dx.doi.org/10.1038/427311a

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. http://dx.doi.org/10.1027/1618-3169/a000243

Duncan, G. J., Ziol-Guest, K. M., & Kalil, A. (2010). Early-childhood poverty and adult attainment, behavior, and health. *Child Development, 81,* 306–325. http://dx.doi.org/10.1111/j.1467-8624.2009.01396.x

Duyck, W., Van Assche, E., Drieghe, D., & Hartsuiker, R. J. (2007). Visual word recognition by bilinguals in a sentence context: Evidence for nonselective lexical access. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 33,* 663–679. http://dx.doi.org/10.1037/0278-7393.33.4.663

Elmer, S., Hänggi, J., & Jäncke, L. (2014). Processing demands upon cognitive, linguistic, and articulatory functions promote grey matter plasticity in the adult multilingual brain: Insights from simultaneous interpreters. *Cortex, 54,* 179–189. http://dx.doi.org/10.1016/j.cortex.2014.02.014

Elmer, S., Meyer, M., Marrama, L., & Jäncke, L. (2011). Intensive language training and attention modulate the involvement of fronto-parietal regions during a non-verbal auditory discrimination task. *European Journal of Neuroscience, 34,* 165–175. http://dx.doi.org/10.1111/j.1460-9568.2011.07728.x

Engel de Abreu, P. M., Cruz-Santos, A., Tourinho, C. J., Martin, R., & Bialystok, E. (2012). Bilingualism enriches the poor: Enhanced cognitive control in low-income minority children. *Psychological Science, 23,* 1364–1371. http://dx.doi.org/10.1177/0956797612443836

Engle, R. W. (2002). Working memory capacity as executive attention. *Current Directions in Psychological Science, 11,* 19–23. http://dx.doi.org/10.1111/1467-8721.00160

Engle, R. W., & Kane, M. J. (2004). Executive attention, working memory capacity, and a two-factor theory of cognitive control. In B. Ross (Ed.), *The psychology of learning and motivation* (Vol. 44, pp. 145–199). New York, NY: Elsevier.

Engle, R. W., Tuholski, S. W., Laughlin, J. E., & Conway, A. R. (1999). Working memory, short-term memory, and general fluid intelligence: A latent-variable approach. *Journal of Experimental Psychology: General, 128,* 309–331. http://dx.doi.org/10.1037/0096-3445.128.3.309

Erickson, K. I., Voss, M. W., Prakash, R. S., Basak, C., Szabo, A., Chaddock, L., . . . Kramer, A. F. (2011). Exercise training increases size of hippocampus and improves memory. *Proceedings of the National Academy of Sciences of the United States of America, 108,* 3017–3022. http://dx.doi.org/10.1073/pnas.1015950108

Eriksen, B. A., & Eriksen, C. W. (1974). Effects of noise letters upon identification of a target letter in a non- search task. *Perception & Psychophysics, 16,* 143–149. http://dx.doi.org/10.3758/BF03203267

Esposito, A. G., Baker-Ward, L., & Mueller, S. (2013). Interference suppression vs. response inhibition: An explanation for the absence of a bilingual advantage in preschoolers' Stroop task performance. *Cognitive Development, 28,* 354–363. http://dx.doi.org/10.1016/j.cogdev.2013.09.002

Fan, J., Fossella, J., Sommer, T., Wu, Y., & Posner, M. I. (2003). Mapping the genetic variation of executive attention onto brain activity. *Proceedings of the National Academy of Sciences of the United States of America, 100,* 7406–7411. http://dx.doi.org/10.1073/pnas.0732088100

Fan, J., McCandliss, B. D., Sommer, T., Raz, A., & Posner, M. I. (2002). Testing the efficiency and independence of attentional networks. *Journal of Cognitive Neuroscience, 14,* 340–347. http://dx.doi.org/10.1162/089892902317361886

Ferjan Ramírez, N., Ramírez, R. R., Clarke, M., Taulu, S., & Kuhl, P. K. (2017). Speech discrimination in 11-month-old bilingual and monolingual infants: A magnetoencephalography study. *Developmental Science, 20,* e12427. http://dx.doi.org/10.1111/desc.12427

Fernandez, M., Tartar, J. L., Padron, D., & Acosta, J. (2013). Neurophysiological marker of inhibition distinguishes language groups on a non-linguistic executive function test. *Brain and Cognition, 83,* 330–336. http://dx.doi.org/10.1016/j.bandc.2013.09.010

Ferreira, N., Owen, A., Mohan, A., Corbett, A., & Ballard, C. (2015). Associations between cognitively stimulating leisure activities, cognitive function and age-related cognitive decline. *International Journal of Geriatric Psychiatry, 30,* 422–430. http://dx.doi.org/10.1002/gps.4155

Foy, J. G., & Mann, V. A. (2014). Bilingual children show advantages in nonverbal auditory executive function task. *The International Journal of Bilingualism, 18,* 717–729. http://dx.doi.org/10.1177/1367006912472263

Friederici, A. D. (2011). The brain basis of language processing: From structure to function. *Physiological Reviews, 91,* 1357–1392. http://dx.doi.org/10.1152/physrev.00006.2011

Friederici, A. D., Pfeifer, E., & Hahne, A. (1993). Event-related brain potentials during natural speech processing: Effects of semantic, morphological and syntactic violations. *Cognitive Brain Research, 1,* 183–192. http://dx.doi.org/10.1016/0926-6410(93)90026-2

Fuller-Thomson, E. (2015). Emerging evidence contradicts the hypothesis that bilingualism delays dementia onset. A Commentary on "age of dementia diagnosis in community dwelling bilingual and monolingual Hispanic Americans" by Lawton et al. (2015). *Cortex, 66,* 170–172. http://dx.doi.org/10.1016/j.cortex.2015.01.024

Fuller-Thomson, E., Milaszewski, D., & Abdelmessih, S. A. (2013). The importance of untangling the role of nativity and bilingualism in Alzheimer's disease. *Cortex, 49,* 1441. http://dx.doi.org/10.1016/j.cortex.2012.10.001

Fuster, J. M. (2002). Frontal lobe and cognitive development. *Journal of Neurocytology, 31,* 373–385. http://dx.doi.org/10.1023/A:1024190429920

Garbin, G., Sanjuan, A., Forn, C., Bustamante, J. C., Rodriguez-Pujadas, A., Belloch, V., . . . Avila, C. (2010). Bridging language and attention: Brain basis of the impact of bilingualism on cognitive control. *NeuroImage, 53,* 1272–1278. http://dx.doi.org/10.1016/j.neuroimage.2010.05.078

García-Pentón, L., Fernandez Garcia, Y., Costello, B., Dunabeitia, J. A., & Carreiras, M. (2016). The neuroanatomy of bilingualism: How to turn a hazy view into the full picture. *Language, Cognition and Neuroscience, 31,* 303–327. http://dx.doi.org/10.1080/23273798.2015.1068944

García-Pentón, L., Pérez Fernández, A., Iturria-Medina, Y., Gillon-Dowens, M., & Carreiras, M. (2014). Anatomical connectivity changes in the bilingual brain. *NeuroImage, 84,* 495–504. http://dx.doi.org/10.1016/j.neuroimage.2013.08.064

Gathercole, V. C., Thomas, E. M., Kennedy, I., Prys, C., Young, N., Viñas Guasch, N., . . . Jones, L. (2014). Does language dominance affect cognitive performance in bilinguals? Lifespan evidence from preschoolers through older adults on card sorting, Simon, and metalinguistic tasks. *Frontiers in Psychology, 5,* 11. http://dx.doi.org/10.3389/fpsyg.2014.00011

Goetz, P. (2003). The effects of bilingualism on theory of mind development. *Bilingualism: Language and Cognition, 6,* 1–15. http://dx.doi.org/10.1017/S1366728903001007

Gold, B. T. (2016). Lifelong bilingualism, cognitive reserve and Alzheimer's disease: A review of findings. *Linguistic Approaches to Bilingualism, 6,* 171–189. http://dx.doi.org/10.1075/lab.14028.gol

Gold, B. T., Johnson, N. F., & Powell, D. K. (2013b). Lifelong bilingualism contributes to cognitive reserve against white matter integrity declines in aging. *Neuropsychologia, 51,* 2841–2846. http://dx.doi.org/10.1016/j.neuropsychologia.2013.09.037

Gold, B. T., Kim, C., Johnson, N. F., Kryscio, R. J., & Smith, C. D. (2013a). Lifelong bilingualism maintains neural efficiency for cognitive control in aging. *The Journal of Neuroscience, 33,* 387–396. http://dx.doi.org/10.1523/JNEUROSCI.3837-12.2013

Gollan, T. H., Salmon, D. P., Montoya, R. I., & Galasko, D. R. (2011). Degree of bilingualism predicts age of diagnosis of Alzheimer's disease in low-education but not in highly educated Hispanics. *Neuropsychologia, 49,* 3826–3830. http://dx.doi.org/10.1016/j.neuropsychologia.2011.09.041

Goral, M., Campanelli, L., & Spiro, A., III. (2015). Language dominance and inhibition abilities in bilingual older adults. *Bilingualism: Language and Cognition, 18,* 79–89. http://dx.doi.org/10.1017/S1366728913000126

Grady, C. L., Luk, G., Craik, F. I., & Bialystok, E. (2015). Brain network activity in monolingual and bilingual older adults. *Neuropsychologia, 66,* 170–181. http://dx.doi.org/10.1016/j.neuropsychologia.2014.10.042

Grainger, J. (1993). Visual word lexicon in bilinguals. In R. Schreuder & B. Weltens (Eds.), *The bilingual lexicon* (pp. 11–25). Amsterdam: John Benjamins. http://dx.doi.org/10.1075/sibil.6.03gra

Green, C. S., & Bavelier, D. (2003). Action video game modifies visual selective attention. *Nature, 423,* 534–537. http://dx.doi.org/10.1038/nature01647

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

Green, D. W., & Abutalebi, J. (2013). Language control in bilinguals: The adaptive control hypothesis. *Journal of Cognitive Psychology, 25,* 515–530. http://dx.doi.org/10.1080/20445911.2013.796377

Greenberg, A., Bellana, B., & Bialystok, E. (2013). Perspective-taking ability in bilingual children: Extending advantages in executive control to spatial reasoning. *Cognitive Development, 28,* 41–50. http://dx.doi.org/10.1016/j.cogdev.2012.10.002

Guzmán-Vélez, E., & Tranel, D. (2015). Does bilingualism contribute to cognitive reserve? Cognitive and neural perspectives. *Neuropsychology, 29,* 139–150. http://dx.doi.org/10.1037/neu0000105

Hack, E., Tyas, S., Dubin, J., Fernandez, M., & Riley, K. (2012). Does multilingualism reduce the risk or delay the onset of dementia?: Findings from the Nun Study. *Alzheimer's & Dementia, 8,* P504. http://dx.doi.org/10.1016/j.jalz.2012.05.1368

Hackman, D. A., Farah, M. J., & Meaney, M. J. (2010). Socioeconomic status and the brain: Mechanistic insights from human and animal research. *Nature Reviews Neuroscience, 11,* 651–659. http://dx.doi.org/10.1038/nrn2897

Hakuta, K. (1986). *Mirror of language: The debate on bilingualism*. New York, NY: Basic Books.

Hall, C. B., Lipton, R. B., Sliwinski, M., Katz, M. J., Derby, C. A., & Verghese, J. (2009). Cognitive activities delay onset of memory decline in persons who develop dementia. *Neurology, 73,* 356–361. http://dx.doi.org/10.1212/WNL.0b013e3181b04ae3

Harrison, T. L., Shipstead, Z., Hicks, K. L., Hambrick, D. Z., Redick, T. S., & Engle, R. W. (2013). Working memory training may increase working memory capacity but not fluid intelligence. *Psychological Science, 24,* 2409–2419. http://dx.doi.org/10.1177/0956797613492984

Hartanto, A., & Yang, H. (2016). Disparate bilingual experiences modulate task-switching advantages: A diffusion-model analysis of the effects of interactional context on switch costs. *Cognition, 150,* 10–19. http://dx.doi.org/10.1016/j.cognition.2016.01.016

Hayne, H. (2006). Age-related changes in infant memory retrieval: Implications for knowledge transfer. In Y. Munakata & J. H. Johnson (Eds.), *Processes of change in brain and cognitive development. Attention and Performance XXI* (pp. 209–231). Oxford: Oxford University Press.

Hebb, D. O. (1949). *The organization of behavior: A neuropsychological theory*. New York, NY: Wiley and Sons.

Hermans, D., Bongaerts, T., De Bot, K., & Schreuder, R. (1998). Producing words in a foreign language: Can speakers prevent interference from their first language? *Bilingualism: Language and Cognition, 1,* 213–229. http://dx.doi.org/10.1017/S1366728998000364

Hernandez, A. E., Greene, M. R., Vaughn, K. A., Francis, D. J., & Grigorenko, E. L. (2015). Beyond the bilingual advantage: The potential role of genes and environment on the development of cognitive control. *Journal of Neurolinguistics, 35,* 109–119. http://dx.doi.org/10.1016/j.jneuroling.2015.04.002

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. http://dx.doi.org/10.1016/j.jml.2013.06.004

Hervais-Adelman, A., Moser-Mercer, B., & Golestani, N. (2015). Brain functional plasticity associated with the emergence of expertise in extreme language control. *Neuroimage, 114,* 264–274. http://dx.doi.org/10.1016/j.neuroimage.2015.03.072

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

Hilchey, M. D., Saint-Aubin, J., & Klein, R. M. (2015). Does bilingual exercise enhance cognitive fitness in non-linguistic executive processing tasks. In J. W. Schwieter (Ed.), *Cambridge handbook of bilingual processing* (pp. 571–585). New York, NY: Cambridge University Press. http://dx.doi.org/10.1017/CBO9781107447257.026

Hosoda, C., Tanaka, K., Nariai, T., Honda, M., & Hanakawa, T. (2013). Dynamic neural network reorganization associated with second language vocabulary acquisition: A multimodal imaging study. *The Journal of Neuroscience, 33,* 13663–13672. http://dx.doi.org/10.1523/JNEUROSCI.0410-13.2013

Incera, S., & McLennan, C. T. (2016). Mouse tracking reveals that bilinguals behave like experts. *Bilingualism: Language and Cognition, 19,* 610–620. http://dx.doi.org/10.1017/S1366728915000218

Iyer, G. K., Alladi, S., Bak, T. H., Shailaja, M., Mamidipudi, A., Rajan, A., . . . Kaul, S. (2014). Does Education play the same role in India as in the

West? *Dementia & Neuropsychologia, 8,* 132–140. http://dx.doi.org/10.1590/S1980-57642014DN82000008

Janus, M., Lee, Y., Moreno, S., & Bialystok, E. (2016). Effects of short-term music and second-language training on executive control. *Journal of Experimental Child Psychology, 144,* 84–97. http://dx.doi.org/10.1016/j.jecp.2015.11.009

Kalashnikova, M., & Mattock, K. (2014). Maturation of executive functioning skills in early sequential bilingualism. *International Journal of Bilingual Education and Bilingualism, 17,* 111–123. http://dx.doi.org/10.1080/13670050.2012.746284

Kalia, V., Wilbourn, M. P., & Ghio, K. (2014). Better early or late? Examining the influence of age of exposure and language proficiency on executive function in early and late bilinguals. *Journal of Cognitive Psychology, 26,* 699–713. http://dx.doi.org/10.1080/20445911.2014.956748

Kang, C., Thoemmes, F., & Lust, B. (2016). Effects of SES on executive attention in Malay–English bilingual children in Singapore. *Bilingualism: Language and Cognition, 19,* 1042–1056. http://dx.doi.org/10.1017/S1366728915000437

Kapa, L. L., & Colombo, J. (2013). Attentional control in early and later bilingual children. *Cognitive Development, 28,* 233–246. http://dx.doi.org/10.1016/j.cogdev.2013.01.011

Karle, J. W., Watter, S., & Shedden, J. M. (2010). Task switching in video game players: Benefits of selective attention but not resistance to proactive interference. *Acta Psychologica, 134,* 70–78. http://dx.doi.org/10.1016/j.actpsy.2009.12.007

Kirk, N. W., Fiala, L., Scott-Brown, K. C., & Kempe, V. (2014). No evidence for reduced Simon cost in elderly bilinguals and bidialectals. *Journal of Cognitive Psychology, 26,* 640–648. http://dx.doi.org/10.1080/20445911.2014.929580

Klein, D., Mok, K., Chen, J. K., & Watkins, K. E. (2014). Age of language learning shapes brain structure: A cortical thickness study of bilingual and monolingual individuals. *Brain and Language, 131,* 20–24. http://dx.doi.org/10.1016/j.bandl.2013.05.014

Klein, R. M., Christie, J., & Parkvall, M. (2016). Does multilingualism affect the incidence of Alzheimer's disease? A worldwide analysis by country. *SSM - Population Health, 2,* 463–467. http://dx.doi.org/10.1016/j.ssmph.2016.06.002

Kolb, B., Mychasiuk, R., Muhammad, A., Li, Y., Frost, D. O., & Gibb, R. (2012). Experience and the developing prefrontal cortex. *Proceedings of the National Academy of Sciences of the United States of America, 109*(Suppl. 2), 17186–17193. http://dx.doi.org/10.1073/pnas.1121251109

Kousaie, S., & Phillips, N. A. (2012a). Ageing and bilingualism: Absence of a "bilingual advantage" in Stroop interference in a nonimmigrant sample. *The Quarterly Journal of Experimental Psychology: Human Experimental Psychology, 65,* 356–369. http://dx.doi.org/10.1080/17470218.2011.604788

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

Kousaie, S., Sheppard, C., Lemieux, M., Monetta, L., & Taler, V. (2014). Executive function and bilingualism in young and older adults. *Frontiers in Behavioral Neuroscience, 8,* 250. http://dx.doi.org/10.3389/fnbeh.2014.00250

Kovács, A. M. (2009). Early bilingualism enhances mechanisms of false-belief reasoning. *Developmental Science, 12,* 48–54. http://dx.doi.org/10.1111/j.1467-7687.2008.00742.x

Kovács, A. M., & Mehler, J. (2009a). Cognitive gains in 7-month-old bilingual infants. *Proceedings of the National Academy of Sciences of the United States of America, 106,* 6556–6560. http://dx.doi.org/10.1073/pnas.0811323106

Kovács, A. M., & Mehler, J. (2009b). Flexible learning of multiple speech structures in bilingual infants. *Science, 325,* 611–612. http://dx.doi.org/10.1126/science.1173947

Kramer, A. F., Bherer, L., Colcombe, S. J., Dong, W., & Greenough, W. T. (2004). Environmental influences on cognitive and brain plasticity during aging. *The Journals of Gerontology, Series A: Biological Sciences and Medical Sciences, 59,* M940–M957. http://dx.doi.org/10.1093/gerona/59.9.M940

Kramer, A. F., & Erickson, K. I. (2007). Capitalizing on cortical plasticity: Influence of physical activity on cognition and brain function. *Trends in Cognitive Sciences, 11,* 342–348. http://dx.doi.org/10.1016/j.tics.2007.06.009

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. *Proceedings of the National Academy of Sciences of the United States of America, 109,* 7877–7881. http://dx.doi.org/10.1073/pnas.1201575109

Krizman, J., Skoe, E., & Kraus, N. (2016). Bilingual enhancements have no socioeconomic boundaries. *Developmental Science, 19,* 881–891. http://dx.doi.org/10.1111/desc.12347

Krizman, J., Skoe, E., Marian, V., & Kraus, N. (2014). Bilingualism increases neural response consistency and attentional control: Evidence for sensory and cognitive coupling. *Brain and Language, 128,* 34–40. http://dx.doi.org/10.1016/j.bandl.2013.11.006

Kroll, J. F., & Bialystok, E. (2013). Understanding the consequences of bilingualism for language processing and cognition. *Journal of Cognitive Psychology, 25,* 497–514. http://dx.doi.org/10.1080/20445911.2013.799170

Kroll, J. F., Dussias, P. E., Bice, K., & Perrotti, L. (2015). Bilingualism, mind, and brain. *Annual Review of Linguistics, 1,* 377–394. http://dx.doi.org/10.1146/annurev-linguist-030514-124937

Kroll, J. F., & Gollan, T. H. (2014). Speech planning in two languages: What bilinguals tell us about language production. In M. Goldrick, V. S. Ferriera, & M. Miozzo (Eds.), *The Oxford handbook of language production* (pp. 165–181). Oxford: Oxford University Press.

Kroll, J. F., Gullifer, J., McClain, R., Rossi, E., & Cruz Martin, M. (2015). Selection and control in bilingual comprehension and production. In J. W. Schwieter (Ed.), *Cambridge handbook of bilingual processing* (pp. 485–507). New York, NY: Cambridge University Press. http://dx.doi.org/10.1017/CBO9781107447257.021

Kuipers, J. R., & Thierry, G. (2011). N400 amplitude reduction correlates with an increase in pupil size. *Frontiers in Human Neuroscience, 5,* 61. http://dx.doi.org/10.3389/fnhum.2011.00061

Kuipers, J. R., & Thierry, G. (2012). Event-related potential correlates of language change detection in bilingual toddlers. *Developmental Cognitive Neuroscience, 2,* 97–102. http://dx.doi.org/10.1016/j.dcn.2011.08.002

Kuipers, J. R., & Thierry, G. (2013). ERP-pupil size correlations reveal how bilingualism enhances cognitive flexibility. *Cortex, 49,* 2853–2860. http://dx.doi.org/10.1016/j.cortex.2013.01.012

Kutas, M., & Federmeier, K. D. (2011). Thirty years and counting: Finding meaning in the N400 component of the event-related brain potential (ERP). *Annual Review of Psychology, 62,* 621–647. http://dx.doi.org/10.1146/annurev.psych.093008.131123

Lappe, C., Trainor, L. J., Herholz, S. C., & Pantev, C. (2011). Cortical plasticity induced by short-term multimodal musical rhythm training. *PLoS ONE, 6,* e21493. http://dx.doi.org/10.1371/journal.pone.0021493

Larson, M. J., Clayson, P. E., & Clawson, A. (2014). Making sense of all the conflict: A theoretical review and critique of conflict-related ERPs. *International Journal of Psychophysiology, 93,* 283–297. http://dx.doi.org/10.1016/j.ijpsycho.2014.06.007

Lawton, D. M., Gasquoine, P. G., & Weimer, A. A. (2015). Age of dementia diagnosis in community dwelling bilingual and monolingual

Hispanic Americans. *Cortex, 66,* 141–145. http://dx.doi.org/10.1016/j.cortex.2014.11.017

Lee, H. L., & Kim, K. H. (2011). Can speaking more languages enhance your creativity? Relationship between bilingualism and creative potential among Korean American students with multicultural link. *Personality and Individual Differences, 50,* 1186–1190. http://dx.doi.org/10.1016/j.paid.2011.01.039

Li, P., Legault, J., & Litcofsky, K. A. (2014). Neuroplasticity as a function of second language learning: Anatomical changes in the human brain. *Cortex, 58,* 301–324. http://dx.doi.org/10.1016/j.cortex.2014.05.001

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. http://dx.doi.org/10.1111/j.1467-9280.2009.02480.x

Ljungberg, J. K., Hansson, P., Adolfsson, R., & Nilsson, L.-G. (2016). The effect of language skills on dementia in a Swedish longitudinal cohort. *Linguistic Approaches to Bilingualism, 6,* 190–204. http://dx.doi.org/10.1075/lab.14031.lju

Lu, L., Bao, G., Chen, H., Xia, P., Fan, X., Zhang, J., . . . Ma, L. (2003). Modification of hippocampal neurogenesis and neuroplasticity by social environments. *Experimental Neurology, 183,* 600–609. http://dx.doi.org/10.1016/S0014-4886(03)00248-6

Luck, S. J. (2014). *An introduction to the event-related potential technique*. Chicago, IL: MIT press.

Luk, G., Anderson, J. A. E., Craik, F. I. M., Grady, C., & Bialystok, E. (2010). Distinct neural correlates for two types of inhibition in bilinguals: Response inhibition versus interference suppression. *Brain and Cognition, 74,* 347–357. http://dx.doi.org/10.1016/j.bandc.2010.09.004

Luk, G., & Bialystok, E. (2013). Bilingualism is not a categorical variable: Interaction between language proficiency and usage. *Journal of Cognitive Psychology, 25,* 605–621. http://dx.doi.org/10.1080/20445911.2013.795574

Luk, G., Bialystok, E., Craik, F. I. M., & Grady, C. L. (2011). Lifelong bilingualism maintains white matter integrity in older adults. *The Journal of Neuroscience, 31,* 16808–16813. http://dx.doi.org/10.1523/JNEUROSCI.4563-11.2011

Luk, G., Green, D. W., Abutalebi, J., & Grady, C. (2012). Cognitive control for language switching in bilinguals: A quantitative meta-analysis of functional neuroimaging studies. *Language and Cognitive Processes, 27,* 1479–1488. http://dx.doi.org/10.1080/01690965.2011.613209

Maguire, E. A., Gadian, D. G., Johnsrude, I. S., Good, C. D., Ashburner, J., Frackowiak, R. S. J., & Frith, C. D. (2000). Navigation-related structural change in the hippocampi of taxi drivers. *Proceedings of the National Academy of Sciences, USA of the United States of America, 97,* 4398–4403. http://dx.doi.org/10.1073/pnas.070039597

Mamiya, P. C., Richards, T. L., Coe, B. P., Eichler, E. E., & Kuhl, P. K. (2016). Brain white matter structure and COMT gene are linked to second-language learning in adults. *Proceedings of the National Academy of Sciences of the United States of America, 113,* 7249–7254. http://dx.doi.org/10.1073/pnas.1606602113

Mani, A., Mullainathan, S., Shafir, E., & Zhao, J. (2013). Poverty impedes cognitive function. *Science, 341,* 976–980. http://dx.doi.org/10.1126/science.1238041

Marian, V., & Spivey, M. (2003). Competing activation in bilingual language processing: Within- and between-language competition. *Bilingualism: Language and Cognition, 6,* 97–115. http://dx.doi.org/10.1017/S1366728903001068

Mårtensson, J., Eriksson, J., Bodammer, N. C., Lindgren, M., Johansson, M., Nyberg, L., & Lövdén, M. (2012). Growth of language-related brain areas after foreign language learning. *NeuroImage, 63,* 240–244. http://dx.doi.org/10.1016/j.neuroimage.2012.06.043

Martin-Rhee, M. M., & Bialystok, E. (2008). The development of two types of inhibitory control in monolingual and bilingual children. *Bilingualism: Language and Cognition, 11,* 81–93. http://dx.doi.org/10.1017/S1366728907003227

Marzecova, A., Asanowicz, D., Kriva, L., & Wodniecka, Z. (2013). The effects of bilingualism on efficiency and lateralization of attentional networks. *Bilingualism: Language and Cognition, 16,* 608–623. http://dx.doi.org/10.1017/S1366728912000569

Mechelli, A., Crinion, J. T., Noppeney, U., O'Doherty, J., Ashburner, J., Frackowiak, R. S., & Price, C. J. (2004). Neurolinguistics: Structural plasticity in the bilingual brain. *Nature, 431,* 757. http://dx.doi.org/10.1038/431757a

Mezzacappa, E. (2004). Alerting, orienting, and executive attention: Developmental properties and sociodemographic correlates in an epidemiological sample of young, urban children. *Child Development, 75,* 1373–1386. http://dx.doi.org/10.1111/j.1467-8624.2004.00746.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. http://dx.doi.org/10.1177/0963721411429458

Miyake, A., Friedman, N. P., Emerson, M. J., Witzki, A. H., Howerter, A., & Wager, T. D. (2000). The unity and diversity of executive functions and their contributions to complex "Frontal Lobe" tasks: A latent variable analysis. *Cognitive Psychology, 41,* 49–100. http://dx.doi.org/10.1006/cogp.1999.0734

Mohades, S. G., Struys, E., Van Schuerbeek, P., Mondt, K., Van De Craen, P., & Luypaert, R. (2012). DTI reveals structural differences in white matter tracts between bilingual and monolingual children. *Brain Research, 1435,* 72–80. http://dx.doi.org/10.1016/j.brainres.2011.12.005

Mohades, S. G., Van Schuerbeek, P., Rosseel, Y., Van De Craen, P., Luypaert, R., & Baeken, C. (2015). White-matter development is different in bilingual and monolingual children: A longitudinal DTI study. *PLoS ONE, 10,* e0117968. http://dx.doi.org/10.1371/journal.pone.0117968

Mor, B., Yitzhaki-Amsalem, S., & Prior, A. (2015). The joint effect of bilingualism and ADHD on executive functions. *Journal of Attention Disorders, 19,* 527–541. http://dx.doi.org/10.1177/1087054714527790

Morales, J., Calvo, A., & Bialystok, E. (2013). Working memory development in monolingual and bilingual children. *Journal of Experimental Child Psychology, 114,* 187–202. http://dx.doi.org/10.1016/j.jecp.2012.09.002

Morales, J., Gómez-Ariza, C. J., & Bajo, M. T. (2013). Dual mechanisms of cognitive control in bilinguals and monolinguals. *Journal of Cognitive Psychology, 25,* 531–546. http://dx.doi.org/10.1080/20445911.2013.807812

Morales, J., Yudes, C., Gómez-Ariza, C. J., & Bajo, M. T. (2015). Bilingualism modulates dual mechanisms of cognitive control: Evidence from ERPs. *Neuropsychologia, 66,* 157–169. http://dx.doi.org/10.1016/j.neuropsychologia.2014.11.014

Moreno, S., Bialystok, E., Wodniecka, Z., & Alain, C. (2010). Conflict resolution in sentence processing by bilinguals. *Journal of Neurolinguistics, 23,* 564–579. http://dx.doi.org/10.1016/j.jneuroling.2010.05.002

Moreno, S., Wodniecka, Z., Tays, W., Alain, C., & Bialystok, E. (2014). Inhibitory control in bilinguals and musicians: Event related potential (ERP) evidence for experience-specific effects. *PLoS ONE, 9,* e94169. http://dx.doi.org/10.1371/journal.pone.0094169

Morford, J. P., Wilkinson, E., Villwock, A., Piñar, P., & Kroll, J. F. (2011). When deaf signers read English: Do written words activate their sign translations? *Cognition, 118,* 286–292. http://dx.doi.org/10.1016/j.cognition.2010.11.006

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

Mychasiuk, R., Zahir, S., Schmold, N., Ilnytskyy, S., Kovalchuk, O., & Gibb, R. (2012). Parental enrichment and offspring development: Modifications to brain, behavior and the epigenome. *Behavioural Brain Research, 228,* 294–298. http://dx.doi.org/10.1016/j.bbr.2011.11.036

Nair, V. K. K., Biedermann, B., & Nickels, L. (in press). Effect of socio-economic status on cognitive control in non-literate bilingual speakers. *Bilingualism: Language and Cognition*. [Advance online publication.]

Nguyen, T.-K., & Astington, J. W. (2014). Reassessing the bilingual advantage in theory of mind and its cognitive underpinnings. *Bilingualism: Language and Cognition, 17,* 396–409. http://dx.doi.org/10.1017/S1366728913000394

Noble, K. G., Houston, S. M., Kan, E., & Sowell, E. R. (2012). Neural correlates of socioeconomic status in the developing human brain. *Developmental Science, 15,* 516–527. http://dx.doi.org/10.1111/j.1467-7687.2012.01147.x

Noble, K. G., McCandliss, B. D., & Farah, M. J. (2007). Socioeconomic gradients predict individual differences in neurocognitive abilities. *Developmental Science, 10,* 464–480. http://dx.doi.org/10.1111/j.1467-7687.2007.00600.x

Noble, K. G., Norman, M. F., & Farah, M. J. (2005). Neurocognitive correlates of socioeconomic status in kindergarten children. *Developmental Science, 8,* 74–87. http://dx.doi.org/10.1111/j.1467-7687.2005.00394.x

Okanda, M., Moriguchi, Y., & Itakura, S. (2010). Language and cognitive shifting: Evidence from young monolingual and bilingual children. *Psychological Reports, 107,* 68–78. http://dx.doi.org/10.2466/03.10.28.PR0.107.4.68-78

Olsen, R. K., Pangelinan, M. M., Bogulski, C., Chakravarty, M. M., Luk, G., Grady, C. L., & Bialystok, E. (2015). The effect of lifelong bilingualism on regional grey and white matter volume. *Brain Research, 1612,* 128–139. http://dx.doi.org/10.1016/j.brainres.2015.02.034

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

Paap, K. R., Johnson, H. A., & Sawi, O. (2015). Bilingual advantages in executive functioning either do not exist or are restricted to very specific and undetermined circumstances. *Cortex, 69,* 265–278. http://dx.doi.org/10.1016/j.cortex.2015.04.014

Paap, K. R., & Sawi, O. (2014). Bilingual advantages in executive functioning: Problems in convergent validity, discriminant validity, and the identification of the theoretical constructs. *Frontiers in Psychology, 5,* 962. http://dx.doi.org/10.3389/fpsyg.2014.00962

Pascual-Leone, A., Amedi, A., Fregni, F., & Merabet, L. B. (2005). The plastic human brain cortex. *Annual Review of Neuroscience, 28,* 377–401. http://dx.doi.org/10.1146/annurev.neuro.27.070203.144216

Peal, E., & Lambert, W. (1962). The relation of bilingualism to intelligence. *Psychological Monographs, 76*(Whole No. 546), 1–23.

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

Peretz, I., & Zatorre, R. J. (2005). Brain organization for music processing. *Annual Review of Psychology, 56,* 89–114. http://dx.doi.org/10.1146/annurev.psych.56.091103.070225

Perquin, M., Vaillant, M., Schuller, A. M., Pastore, J., Dartigues, J. F., Lair, M. L., . . . the MemoVie Group. (2013). Lifelong exposure to multilingualism: New evidence to support cognitive reserve hypothesis. *PLoS ONE, 8,* e62030. http://dx.doi.org/10.1371/journal.pone.0062030

Petrosini, L., De Bartolo, P., Foti, F., Gelfo, F., Cutuli, D., Leggio, M. G., & Mandolesi, L. (2009). On whether the environmental enrichment may provide cognitive and brain reserves. *Brain Research Reviews, 61,* 221–239. http://dx.doi.org/10.1016/j.brainresrev.2009.07.002

Pliatsikas, C., Moschopoulou, E., & Saddy, J. D. (2015). The effects of bilingualism on the white matter structure of the brain. *Proceedings of the National Academy of Sciences of the United States of America, 112,* 1334–1337. http://dx.doi.org/10.1073/pnas.1414183112

Poarch, G. J., & Bialystok, E. (2015). Bilingualism as a model for multitasking. *Developmental Review, 35,* 113–124. http://dx.doi.org/10.1016/j.dr.2014.12.003

Poarch, G. J., & van Hell, J. G. (2012). Executive functions and inhibitory control in multilingual children: Evidence from second-language learners, bilinguals, and trilinguals. *Journal of Experimental Child Psychology, 113,* 535–551. http://dx.doi.org/10.1016/j.jecp.2012.06.013

Poline, J.-B., Vandenberghe, R., Holmes, A. P., Friston, K. J., & Frackowiak, R. S. J. (1996). Reproducibility of PET activation studies: Lessons from a multi-center European experiment. EU concerted action on functional imaging. *NeuroImage, 4,* 34–54. http://dx.doi.org/10.1006/nimg.1996.0027

Pons, F., Bosch, L., & Lewkowicz, D. J. (2015). Bilingualism modulates infants' selective attention to the mouth of a talking face. *Psychological Science, 26,* 490–498. http://dx.doi.org/10.1177/0956797614568320

Posner, M. I., & Petersen, S. E. (1990). The attention system of the human brain. *Annual Review of Neuroscience, 13,* 25–42. http://dx.doi.org/10.1146/annurev.ne.13.030190.000325

Posner, M. I., & Rothbart, M. K. (2005). Influencing brain networks: Implications for education. *Trends in Cognitive Sciences, 9,* 99–103. http://dx.doi.org/10.1016/j.tics.2005.01.007

Poulin-Dubois, D., Blaye, A., Coutya, J., & Bialystok, E. (2011). The effects of bilingualism on toddlers' executive functioning. *Journal of Experimental Child Psychology, 108,* 567–579.

Prior, A., & Gollan, T. H. (2013). The elusive link between language control and executive control: A case of limited transfer. *Journal of Cognitive Psychology, 25,* 622–645. http://dx.doi.org/10.1080/20445911.2013.821993

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

Rauscher, F. H., Shaw, G. L., & Ky, K. N. (1993). Music and spatial task performance. *Nature, 365,* 611. http://dx.doi.org/10.1038/365611a0

Ressel, V., Pallier, C., Ventura-Campos, N., Díaz, B., Roessler, A., Ávila, C., & Sebastián-Gallés, N. (2012). An effect of bilingualism on the auditory cortex. *The Journal of Neuroscience, 32,* 16597–16601. http://dx.doi.org/10.1523/JNEUROSCI.1996-12.2012

Riggs, N. R., Shin, H. S., Unger, J. B., Spruijt-Metz, D., & Pentz, M. A. (2014). Prospective associations between bilingualism and executive function in Latino children: Sustained effects while controlling for biculturalism. *Journal of Immigrant and Minority Health, 16,* 914–921. http://dx.doi.org/10.1007/s10903-013-9838-0

Riesenhuber, M. (2004). An action video game modifies visual processing. *Trends in Neurosciences, 27,* 72–74. http://dx.doi.org/10.1016/j.tins.2003.11.004

Rodríguez-Pujadas, A., Sanjuán, A., Fuentes, P., Ventura-Campos, N., Barrós-Loscertales, A., & Ávila, C. (2014). Differential neural control in early bilinguals and monolinguals during response inhibition. *Brain and Language, 132,* 43–51. http://dx.doi.org/10.1016/j.bandl.2014.03.003

Rodríguez-Pujadas, A., Sanjuán, A., Ventura-Campos, N., Román, P., Martin, C., Barceló, F., . . . Avila, C. (2013). Bilinguals use language-control brain areas more than monolinguals to perform non-linguistic switching tasks. *PLoS ONE, 8,* e73028. http://dx.doi.org/10.1371/journal.pone.0073028

Rosenzweig, M. R., Krech, D., Bennett, E. L., & Diamond, M. C. (1962). Effects of environmental complexity and training on brain chemistry and anatomy: A replication and extension. *Journal of Comparative and Physiological Psychology, 55,* 429–437. http://dx.doi.org/10.1037/h0041137

Rueda, M. R., Checa, P., & Cómbita, L. M. (2012). Enhanced efficiency of the executive attention network after training in preschool children: Immediate changes and effects after two months. *Developmental Cog-*

*nitive Neuroscience, 2*(Suppl. 1), S192–S204. http://dx.doi.org/10.1016/j.dcn.2011.09.004

Rueda, M. R., Fan, J., McCandliss, B. D., Halparin, J. D., Gruber, D. B., Lercari, L. P., & Posner, M. I. (2004). Development of attentional networks in childhood. *Neuropsychologia, 42,* 1029–1040. http://dx.doi.org/10.1016/j.neuropsychologia.2003.12.012

Rueda, M. R., Posner, M. I., & Rothbart, M. K. (2005). The development of executive attention: Contributions to the emergence of self-regulation. *Developmental Neuropsychology, 28,* 573–594. http://dx.doi.org/10.1207/s15326942dn2802_2

Salvatierra, J. L., & Rosselli, M. (2011). The effect of bilingualism and age on inhibitory control. *The International Journal of Bilingualism, 15,* 26–37. http://dx.doi.org/10.1177/1367006910371021

Sanders, A. E., Hall, C. B., Katz, M. J., & Lipton, R. B. (2012). Non-native language use and risk of incident dementia in the elderly. *Journal of Alzheimers Disease, 29,* 99–108. http://dx.doi.org/10.3233/JAD-2011-111631

Scaltritti, M., Peressotti, F., & Miozzo, M. (2017). Bilingual advantage and language switch: What's the linkage? *Bilingualism: Language and Cognition, 20,* 80–97.

Scarmeas, N., Albert, S. M., Manly, J. J., & Stern, Y. (2006). Education and rates of cognitive decline in incident Alzheimer's disease. *Journal of Neurology, Neurosurgery, and Psychiatry, 77,* 308–316. http://dx.doi.org/10.1136/jnnp.2005.072306

Scarmeas, N., Levy, G., Tang, M., Manly, J., & Stern, Y. (2001). Influence of leisure activity on the incidence of Alzheimer's disease. *Neurology, 57,* 2236–2242. http://dx.doi.org/10.1212/WNL.57.12.2236

Schlegel, A. A., Rudelson, J. J., & Tse, P. U. (2012). White matter structure changes as adults learn a second language. *Journal of Cognitive Neuroscience, 24,* 1664–1670. http://dx.doi.org/10.1162/jocn_a_00240

Schweizer, T., Craik, F. I. M., & Bialystok, E. (2013). Bilingualism, not immigration status, is associated with maintained cognitive level in Alzheimer's disease. *Cortex, 49,* 1442–1443. http://dx.doi.org/10.1016/j.cortex.2012.10.012

Schweizer, T. A., Ware, J., Fischer, C. E., Craik, F. I. M., & Bialystok, E. (2012). Bilingualism as a contributor to cognitive reserve: Evidence from brain atrophy in Alzheimer's disease. *Cortex, 48,* 991–996. http://dx.doi.org/10.1016/j.cortex.2011.04.009

Sebastián-Gallés, N., Albareda-Castellot, B., Weikum, W. M., & Werker, J. F. (2012). A bilingual advantage in visual language discrimination in infancy. *Psychological Science, 23,* 994–999. http://dx.doi.org/10.1177/0956797612436817

Shah, A. K., Mullainathan, S., & Shafir, E. (2012). Some consequences of having too little. *Science, 338,* 682–685. http://dx.doi.org/10.1126/science.1222426

Shipstead, Z., Harrison, T. L., & Engle, R. W. (2015). Working memory capacity and the scope and control of attention. *Attention, Perception, & Psychophysics, 77,* 1863–1880. http://dx.doi.org/10.3758/s13414-015-0899-0

Singh, L., Fu, C. S., Rahman, A. A., Hameed, W. B., Sanmugam, S., Agarwal, P., . . . the GUSTO Research Team. (2015). Back to basics: A bilingual advantage in infant visual habituation. *Child Development, 86,* 294–302. http://dx.doi.org/10.1111/cdev.12271

Singh, N., & Mishra, R. K. (2012). Does language proficiency modulate oculomotor control? Evidence from Hindi–English bilinguals. *Bilingualism: Language and Cognition, 15,* 771–781. http://dx.doi.org/10.1017/S1366728912000065

Singh, N., & Mishra, R. K. (2013). Second language proficiency modulates conflict-monitoring in an oculomotor Stroop task: Evidence from Hindi-English bilinguals. *Frontiers in Psychology, 4,* 322. http://dx.doi.org/10.3389/fpsyg.2013.00322

Sorge, G. B., Toplak, M. E., & Bialystok, E. (2017). Interactions between levels of attention ability and levels of bilingualism in children's executive functioning. *Developmental Science, 20,* e12408. http://dx.doi.org/10.1111/desc.12408

Soveri, A., Rodriguez-Fornells, A., & Laine, M. (2011). Is there a relationship between language switching and executive functions in bilingualism? Introducing a within group analysis approach. *Frontiers in Psychology, 2,* 183. http://dx.doi.org/10.3389/fpsyg.2011.00183

Spreng, R. N., Sepulcre, J., Turner, G. R., Stevens, W. D., & Schacter, D. L. (2013). Intrinsic architecture underlying the relations among the default, dorsal attention, and frontoparietal control networks of the human brain. *Journal of Cognitive Neuroscience, 25,* 74–86. http://dx.doi.org/10.1162/jocn_a_00281

Stein, M., Federspiel, A., Koenig, T., Wirth, M., Strik, W., Wiest, R., . . . Dierks, T. (2012). Structural plasticity in the language system related to increased second language proficiency. *Cortex, 48,* 458–465. http://dx.doi.org/10.1016/j.cortex.2010.10.007

Stern, Y. (2002). What is cognitive reserve? Theory and research application of the reserve concept. *Journal of the International Neuropsychological Society, 8,* 448–460. http://dx.doi.org/10.1017/S1355617702813248

Stevens, C., Lauinger, B., & Neville, H. (2009). Differences in the neural mechanisms of selective attention in children from different socioeconomic backgrounds: An event-related brain potential study. *Developmental Science, 12,* 634–646. http://dx.doi.org/10.1111/j.1467-7687.2009.00807.x

Stocco, A., & Prat, C. S. (2014). Bilingualism trains specific brain circuits involved in flexible rule selection and application. *Brain and Language, 137,* 50–61. http://dx.doi.org/10.1016/j.bandl.2014.07.005

Stocco, A., Yamasaki, B., Natalenko, R., & Prat, C. S. (2014). Bilingual brain training: A neurobiological framework of how bilingual experience improves executive function. *The International Journal of Bilingualism, 18,* 67–92. http://dx.doi.org/10.1177/1367006912456617

Strobach, T., Becker, M., Schubert, T., & Kuhn, S. (2015). Better dual-task processing in simultaneous interpreters. *Front Psychol, 6,* 1590. http://dx.doi.org/10.3389/fpsyg.2015.01590

Sullivan, M. D., Janus, M., Moreno, S., Astheimer, L., & Bialystok, E. (2014). Early stage second-language learning improves executive control: Evidence from ERP. *Brain and Language, 139,* 84–98. http://dx.doi.org/10.1016/j.bandl.2014.10.004

Tao, L., Marzecová, 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. http://dx.doi.org/10.3389/fpsyg.2011.00123

Teubner-Rhodes, S. E., Mishler, A., Corbett, R., Andreu, L., Sanz-Torrent, M., Trueswell, J. C., & Novick, J. M. (2016). The effects of bilingualism on conflict monitoring, cognitive control, and garden-path recovery. *Cognition, 150,* 213–231. http://dx.doi.org/10.1016/j.cognition.2016.02.011

Thierry, G., & Wu, Y. J. (2007). Brain potentials reveal unconscious translation during foreign-language comprehension. *Proceedings of the National Academy of Sciences of the United States of America, 104,* 12530–12535. http://dx.doi.org/10.1073/pnas.0609927104

Thomas-Sunesson, D., Hakuta, K., & Bialystok, E. (in press). Degree of bilingualism modifies executive control in Hispanic children in the US. *International Journal of Bilingual Education and Bilingualism.*

Thorpe, S., Fize, D., & Marlot, C. (1996). Speed of processing in the human visual system. *Nature, 381,* 520–522. http://dx.doi.org/10.1038/381520a0

Tran, C. D., Arredondo, M. M., & Yoshida, H. (2015). Differential effects of bilingualism and culture on early attention: A longitudinal study in the U. S., Argentina, and Vietnam. *Frontiers in Psychology, 6,* 795. http://dx.doi.org/10.3389/fpsyg.2015.00795

Treccani, B., Argyri, E., Sorace, A., & Della Sala, S. (2009). Spatial negative priming in bilingualism. *Psychonomic Bulletin & Review, 16,* 320–327. http://dx.doi.org/10.3758/PBR.16.2.320

Tse, C. S., & Altarriba, J. (2014). The relationship between language proficiency and attentional control in Cantonese-English bilingual children: Evidence from Simon, Simon switching, and working memory tasks. *Frontiers in Psychology, 5,* 954. http://dx.doi.org/10.3389/fpsyg.2014.00954

Vaughn, K. A., Ramos Nuñez, A. I., Greene, M. R., Munson, B. A., Grigorenko, E. L., & Hernandez, A. E. (2016). Individual differences in the bilingual brain: The role of language background and DRD2 genotype in verbal and non-verbal cognitive control. *Journal of Neurolinguistics, 40,* 112–127. http://dx.doi.org/10.1016/j.jneuroling.2016.06.008

Vemuri, P., Lesnick, T. G., Przybelski, S. A., Knopman, D. S., Roberts, R. O., Lowe, V. J., . . . Jack, C. R., Jr. (2012). Effect of lifestyle activities on Alzheimer disease biomarkers and cognition. *Annals of Neurology, 72,* 730–738. http://dx.doi.org/10.1002/ana.23665

Verreyt, N., Woumans, E. V. Y., Vandelanotte, D., Szmalec, A., & Duyck, W. (2016). The influence of language-switching experience on the bilingual executive control advantage. *Bilingualism: Language and Cognition, 19,* 181–190. http://dx.doi.org/10.1017/S1366728914000352

Vincent, J. L., Kahn, I., Snyder, A. Z., Raichle, M. E., & Buckner, R. L. (2008). Evidence for a frontoparietal control system revealed by intrinsic functional connectivity. *Journal of Neurophysiology, 100,* 3328–3342. http://dx.doi.org/10.1152/jn.90355.2008

von Bastian, C. C., Souza, A. S., & Gade, M. (2016). No evidence for bilingual cognitive advantages: A test of four hypotheses. *Journal of Experimental Psychology: General, 145,* 246–258. http://dx.doi.org/10.1037/xge0000120

Vygotsky, L. S. (1962). *Thought and language*. Cambridge, MA: MIT Press. http://dx.doi.org/10.1037/11193-000

Waber, D. P., De Moor, C., Forbes, P. W., Almli, C. R., Botteron, K. N., Leonard, G., . . . the Brain Development Cooperative Group. (2007). The NIH MRI study of normal brain development: Performance of a population based sample of healthy children aged 6 to 18 years on a neuropsychological battery. *Journal of the International Neuropsychological Society, 13,* 729–746. http://dx.doi.org/10.1017/S1355617707070841

Weber, R. C., Johnson, A., Riccio, C. A., & Liew, J. (2016). Balanced bilingualism and executive functioning in children. *Bilingualism: Language and Cognition, 19,* 425–431. http://dx.doi.org/10.1017/S1366728915000553

Weikum, W. M., Vouloumanos, A., Navarra, J., Soto-Faraco, S., Sebastián-Gallés, N., & Werker, J. F. (2007). Visual language discrimination in infancy. *Science, 316,* 1159. http://dx.doi.org/10.1126/science.1137686

Weinreich, U. (1953). *Languages in contact*. New York, NY: Linguistic Circle of New York.

Werker, J. F., & Tees, R. C. (1983). Developmental changes across childhood in the perception of non-native speech sounds. *Canadian Journal of Psychology, 37,* 278–286. http://dx.doi.org/10.1037/h0080725

Werker, J. F., & Tees, R. C. (1984). Cross-language speech perception: Evidence for perceptual reorganization during the first year of life. *Infant Behavior and Development, 7,* 49–63. http://dx.doi.org/10.1016/S0163-6383(84)80022-3

Wiebe, S. A., Espy, K. A., & Charak, D. (2008). Using confirmatory factor analysis to understand executive control in preschool children: I. Latent structure. *Developmental Psychology, 44,* 575–587. http://dx.doi.org/10.1037/0012-1649.44.2.575

Wilson, R., Barnes, L., & Bennett, D. (2003). Assessment of lifetime participation in cognitively stimulating activities. *Journal of Clinical and Experimental Neuropsychology, 25,* 634–642. http://dx.doi.org/10.1076/jcen.25.5.634.14572

Wilson, R. S., Boyle, P. A., Yang, J., James, B. D., & Bennett, D. A. (2015). Early life instruction in foreign language and music and incidence of mild cognitive impairment. *Neuropsychology, 29,* 292–302. http://dx.doi.org/10.1037/neu0000129

Wilson, R. S., Mendes De Leon, C. F., Barnes, L. L., Schneider, J. A., Bienias, J. L., Evans, D. A., & Bennett, D. A. (2002). Participation in cognitively stimulating activities and risk of incident Alzheimer disease. *Journal of the American Medical Association, 287,* 742–748. http://dx.doi.org/10.1001/jama.287.6.742

Wimmer, M. C., & Marx, C. (2014). Inhibitory processes in visual perception: A bilingual advantage. *Journal of Experimental Child Psychology, 126,* 412–419. http://dx.doi.org/10.1016/j.jecp.2014.03.004

Wimo, A., Jonsson, L., & Winblad, B. (2006). An estimate of the worldwide prevalence and direct costs of dementia in 2003. *Dementia and Geriatric Cognitive Disorders, 21,* 175–181. http://dx.doi.org/10.1159/000090733

Woumans, E., Ceuleers, E., Van der Linden, L., Szmalec, A., & Duyck, W. (2015). Verbal and nonverbal cognitive control in bilinguals and interpreters. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 41,* 1579–1586. http://dx.doi.org/10.1037/xlm0000107

Wu, Y. J., Zhang, H., & Guo, T. (2016). Does speaking two dialects in daily life affect executive functions? An event-related potential study. *PLoS ONE, 11,* e0150492. http://dx.doi.org/10.1371/journal.pone.0150492

Yang, H., Hartanto, A., & Yang, S. (2016). The complex nature of bilinguals' language usage modulates task-switching outcomes. *Frontiers in Psychology, 7,* 560. [Advance online publication.] http://dx.doi.org/10.3389/fpsyg.2016.00560

Yang, S., & Yang, H. (2016). Bilingual effects on deployment of the attention system in linguistically and culturally homogeneous children and adults. *Journal of Experimental Child Psychology, 146,* 121–136. http://dx.doi.org/10.1016/j.jecp.2016.01.011

Yang, S., Yang, H., & Lust, B. (2011). Early childhood bilingualism leads to advances in executive attention: Dissociating culture and language. *Bilingualism: Language and Cognition, 14,* 412–422. http://dx.doi.org/10.1017/S1366728910000611

Yoshida, H., Tran, D. N., Benitez, V., & Kuwabara, M. (2011). Inhibition and adjective learning in bilingual and monolingual children. *Frontiers in Psychology, 2,* 210. http://dx.doi.org/10.3389/fpsyg.2011.00210

Zahodne, L. B., Glymour, M. M., Sparks, C., Bontempo, D., Dixon, R. A., MacDonald, S. W., & Manly, J. J. (2011). Education does not slow cognitive decline with aging: 12-year evidence from the Victoria longitudinal study. *Journal of the International Neuropsychological Society, 17,* 1039–1046. http://dx.doi.org/10.1017/S1355617711001044

Zahodne, L. B., Schofield, P. W., Farrell, M. T., Stern, Y., & Manly, J. J. (2014). Bilingualism does not alter cognitive decline or dementia risk among Spanish-speaking immigrants. *Neuropsychology, 28,* 238–246. http://dx.doi.org/10.1037/neu0000014

Zelazo, P. D., Frye, D., & Rapus, T. (1996). An age-related dissociation between knowing rules and using them. *Cognitive Development, 11,* 37–63. http://dx.doi.org/10.1016/S0885-2014(96)90027-1

Zhou, B., & Krott, A. (2016). Data trimming procedure can eliminate bilingual cognitive advantage. *Psychonomic Bulletin & Review, 23,* 1221–1230. http://dx.doi.org/10.3758/s13423-015-0981-6

Received June 20, 2016
Revision received December 13, 2016
Accepted December 20, 2016 ■