

Cognitive and Linguistic Processing in the Bilingual Mind

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ABSTRACT

The article reports research investigating the way bilingualism affects cognitive and linguistic performance across the lifespan. In general, bilingualism appears to have both benefits and costs. Regarding costs, bilinguals typically have lower formal language proficiency than monolinguals do; for example, they have smaller vocabularies and weaker access to lexical items. The benefits, however, are that bilinguals exhibit enhanced executive control in nonverbal tasks requiring conflict resolution, such as the Stroop and Simon tasks. These patterns and their consequences are illustrated and discussed. We also propose some suggestions regarding underlying mechanisms for these effects.

Keywords: executive function; language proficiency; development; aging

It is an obvious fact that human cognitive processes are heavily dependent on linguistic abilities, but does the number of languages one speaks also shape the mind? For many years, responses to this question emphasized the negative consequences of bilingualism, even warning that speaking two languages created retardation in children! So it was surprising when a radically different answer was offered by Peal and Lambert (1962); they showed that bilingual francophone children in Montreal outperformed monolingual English-speaking children on a wide variety of measures. The modern era of bilingual research was born.

The great bulk of research since that time has compared linguistic processing in the bilingual individual's two languages. But the question we address here is different: How does bilingualism affect cognitive and linguistic processes in general? Increasingly, evidence has pointed to broadly based effects of experience on cognitive and brain organization, such as the enlarged hippocampus in London taxi drivers (Maguire et al., 2000). Is bilingualism an experience with the potential to alter the mind and brain?

Studies seeking evidence for bilingual effects on development began with the conservative assumption that any detectable effect of a linguistic experience would be found in the domain of linguistic competence. Thus, during the 1970s and 1980s, investigators explored the development of metalinguistic awareness in monolingual and bilingual children. Metalinguistic awareness is the explicit knowledge of linguistic structure and the ability to access it intentionally, abilities that are crucial to children's development of complex uses of language and the acquisition of literacy.

The early research on metalinguistic development in monolingual and bilingual children revealed an important divide. In several studies (e.g., Bialystok, 1988; Cromdal, 1999), monolingual and bilingual children were equally capable of detecting grammatical violations in

meaningful sentences (e.g., “Apples grew on trees”), a typical measure of metalinguistic functioning in children. When the sentences were semantically anomalous, however (e.g., “Apples grow on noses”), successful performance requires the ability to ignore the misleading meaning and focus only on the grammar. Bilingual children were more accurate in these cases. Thus, counterintuitively, their additional linguistic experience did not benefit linguistic knowledge but rather some process associated with access to that knowledge. Put this way, the bilingual advantage in judging sentences has less to do with metalinguistic knowledge than with an attentional advantage in selectivity and inhibition. These processes are signature components of executive functioning.

BILINGUALISM AND THE EXECUTIVE FUNCTION SYSTEM

The development of the executive-function system, located in the prefrontal cortex, is the most crucial cognitive achievement in early childhood. Children gradually master the ability to control attention, inhibit distraction, monitor sets of stimuli, expand working memory, and shift between tasks. Importantly, these are the same cognitive processes that show the first evidence of decline in aging. Therefore, if bilingualism affects executive functioning, the impact should be found across the entire cognitive system and throughout the entire lifespan.

Accumulating evidence supports the claim for a lifelong positive effect of bilingualism on these executive-control processes. Typically, the research compares performance by monolinguals and bilinguals on tasks that are superficially similar but include one condition that additionally requires some aspect of executive control. For example, Bialystok and colleagues (Bialystok, 1999; Bialystok & Martin, 2004) gave the dimensional-change card-sort task (DCCS; Zelazo, Frye, & Rapus, 1996) to 4- and 5-year-old children. In this task, children sort cards either by the color (red, blue) or shape (circle, square) of diagrams on the cards. Participants first sort

by one dimension (e.g., color) but are later instructed to switch to the other dimension (e.g., shape). Young children typically persist in sorting by the original dimension. However, bilinguals were more successful in switching to the second dimension following the rule change, indicating higher levels of executive control. Figure 1 presents the scores on the critical post-switch condition in two studies.

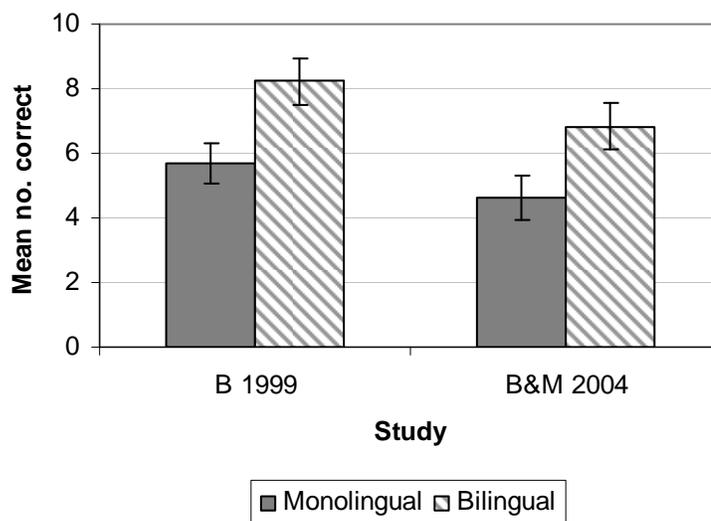


Fig. 1. Mean number correct (out of 10) and standard error by language group (monolingual or bilingual) in the post-switch condition of the dimension-change card-sort task in two studies. B 1999 = Bialystok (1999); B&M 2004 = Bialystok & Martin (2004).

In another study, 6-year-old children were comparable in locating a hidden shape in a complex drawing in the Children's Embedded Figures Task, but bilinguals were more able to change their interpretation of an ambiguous figure (e.g., the duck-rabbit) to acknowledge the other image (Bialystok & Shapero, 2005). Both tasks require perceptual analysis, but only the ambiguous-figures task requires inhibiting the original meaning of the stimulus. Carlson and Meltzoff (2008) refined this position by demonstrating an advantage for 6-year-old bilingual

children in executive-control tasks that require inhibition of attention to conflicting response options but not in tasks requiring inhibition of a habitual response to a familiar stimulus. Kovács and Mehler (2009) recently extended this pattern to infants. They found that 7-month old infants raised in bilingual households were better able to switch responses after a rule shift (cf., DCCS) than were their peers raised in monolingual households.

Research with adults has revealed parallel results, showing for example faster bilingual responding to conflict conditions in the Stroop task (Bialystok, Craik, & Luk, 2008a) and flanker task (Costa, Hernández, & Sebastián-Gallés, 2008). Bilinguals were less disrupted than monolinguals when the response to a stimulus required participants to ignore a competing but irrelevant feature of the stimulus. This enhanced bilingual performance persists into older age, sometimes showing a slower rate of decline than that found in healthy older monolinguals.

One illustrative experiment by Bialystok and colleagues (2004) involved several reaction-time (RT) conditions. In the simplest condition, one of two color patches was presented in the center of a computer screen and the task was to press the relevant response key as rapidly as possible. In another condition, the colored patch appeared at the side of the screen, either above the relevant key (congruent) or on the opposite (incongruent) side. The longer time needed to respond in the incongruent presentation compared to the congruent one is called the Simon effect; larger Simon effects imply greater difficulty in suppressing the irrelevant spatial information. Figure 2a shows results for the first condition (simple RT) as a function of age and language group, and Figure 2b shows the Simon Effect for the same groups. Older participants respond more slowly, but there are no differences between monolinguals and bilinguals on the simple condition (Fig. 2a). However, the size of the Simon effect in Figure 2b indicates a larger disruption for monolinguals than bilinguals that appears to increase in the older groups. This

result suggests that bilingualism may protect against age-related cognitive decline—at least in the ability to inhibit the disruptive effects of misleading stimuli.

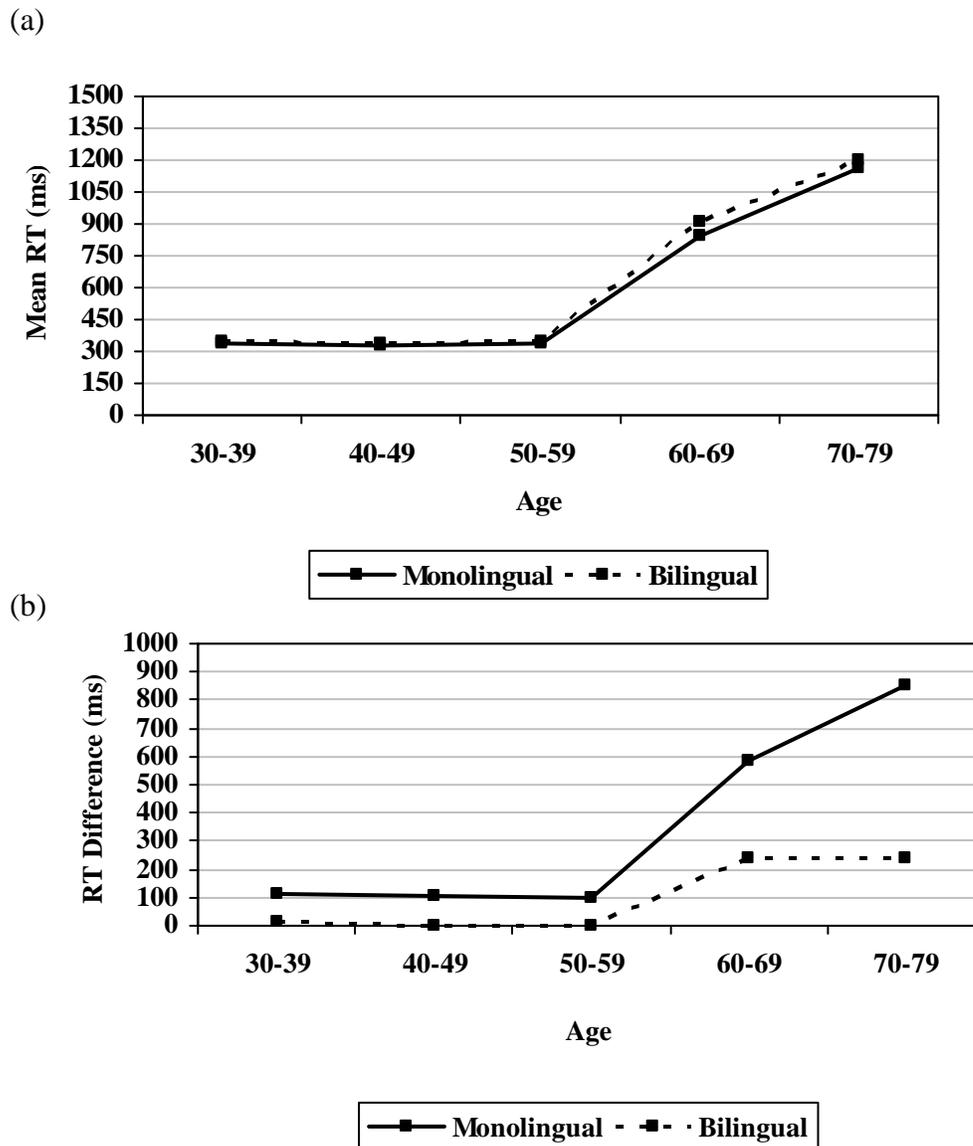


Fig. 2. Mean reaction time (RT) by decade for monolinguals and bilinguals. (a) Mean RT for control condition. (b) Mean RT cost as the difference between congruent and incongruent trials (Simon effect). From Bialystok, Craik, Klein, & Viswanathan (2004).

LINGUISTIC ABILITY AND EXECUTIVE CONTROL

The bilingual story is not all positive, however. Studies of vocabulary knowledge have consistently reported lower scores for bilinguals in each language than for monolingual speakers of that language, and this deficit appears at all ages across the lifespan (Bialystok, 2001). In a study examining receptive vocabulary scores in English for over 1,700 children between the ages of 3- and 10-years old, monolingual children obtained higher scores than bilingual children at every age, even though all the bilingual children were fluent in English and used it daily at school (Bialystok, Luk, Peets, & Yang, in press). Similarly, studies of language processing in adults have documented disadvantages for bilinguals in tasks that require rapid lexical access and retrieval. Bilinguals are slower and commit more errors in picture naming even in their dominant language, obtain lower scores on verbal-fluency tasks, experience more tip-of-the-tongue states, and demonstrate more interference in lexical decision (Michael & Gollan, 2005). Although these deficits are not apparent in conversational interactions with bilinguals, their persistence in controlled experiments signals a pervasive negative impact of two language systems on linguistic performance. This pattern of positive and negative effects prompts two related questions: First, do the two conflicting influences co-exist in the same individuals? And second, if they do, are the effects independent or interactive?

The first question was addressed in a study of younger and older adults by Bialystok et al. (2008a). In this study, four groups of participants who were younger (20–30 years) or older (60–80 years) monolinguals or bilinguals completed tasks that assessed either language proficiency and lexical access or nonverbal executive functioning. The main findings were that monolinguals performed better on the former set of tasks, whereas bilinguals performed better on the latter. Younger participants showed higher levels of performance on most tasks, although the older

adults were better on tasks tapping vocabulary knowledge. Additionally, there was some evidence for larger language–group differences in older participants on executive control tasks, suggesting that bilingualism may compensate to some extent for the typical age-related decline of executive functions. These results appear to show that lexical and executive processes are independent, but on other tasks these demands are often combined—language processing frequently requires executive control. How do monolinguals and bilinguals perform in such situations?

We have investigated these interactions through several paradigms. One example is the release from proactive interference (PI) task, in which participants are asked to recall items from successively presented lists of words that belong to the same semantic category. With each new list, interference builds up from previous lists and performance declines as participants become less able to encode new specifics and to discriminate the current list at retrieval. After three such lists, the fourth list presents words from a different semantic category and recall performance is restored. Executive control is involved in the ability to focus on the current list at encoding and retrieval. In two studies, PI was shown to be less problematic for both 7-year-old children and young adults who were bilingual than for their monolingual counterparts, in spite of lower proficiency on a vocabulary test in both cases (Bialystok & Feng, 2009).

A clear dissociation between levels of language proficiency and executive control over accessing that language is possible through the two subtests of the verbal-fluency test. This is a neuropsychological assessment instrument used to diagnose difficulties in brain function. In the semantic-fluency condition, participants are given 60 seconds to generate words that belong to a particular category, such as animals. Because the instruction is compatible with the organizational principle of linguistic representation—that is, there are closer associative links

among names for animals than between the name for an animal and the name for a flower—the number of responses provides an index of vocabulary size or language proficiency. In the letter-fluency condition, participants are asked to generate words that begin with a particular letter and to observe a set of restrictions: No proper names, no numbers, and no variations on the same word. Given the combination of the requirement for an effortful search through representational space and the restrictions that require monitoring and working memory, the letter-fluency task assesses both language proficiency and executive control. Typically, bilinguals have smaller vocabularies than monolinguals do, and the usual finding is that bilinguals generate fewer words on the semantic-fluency task than do monolinguals but that they sometimes perform as well as monolinguals on the letter fluency task. A study by Bialystok, Craik, and Luk (2008b) selected bilinguals who either performed more poorly than monolinguals on a vocabulary test or were matched in performance to monolinguals for vocabulary, with all other cognitive measures equivalent for the three groups. Consistent with previous research, the unmatched bilinguals generated fewer words in the category task than did monolinguals or vocabulary-matched bilinguals. However, the vocabulary-matched bilinguals generated *more* words than did monolinguals or unmatched bilinguals on letter fluency, showing the advantage of executive control once proficiency deficits were eliminated. These results are shown in Figure 3.

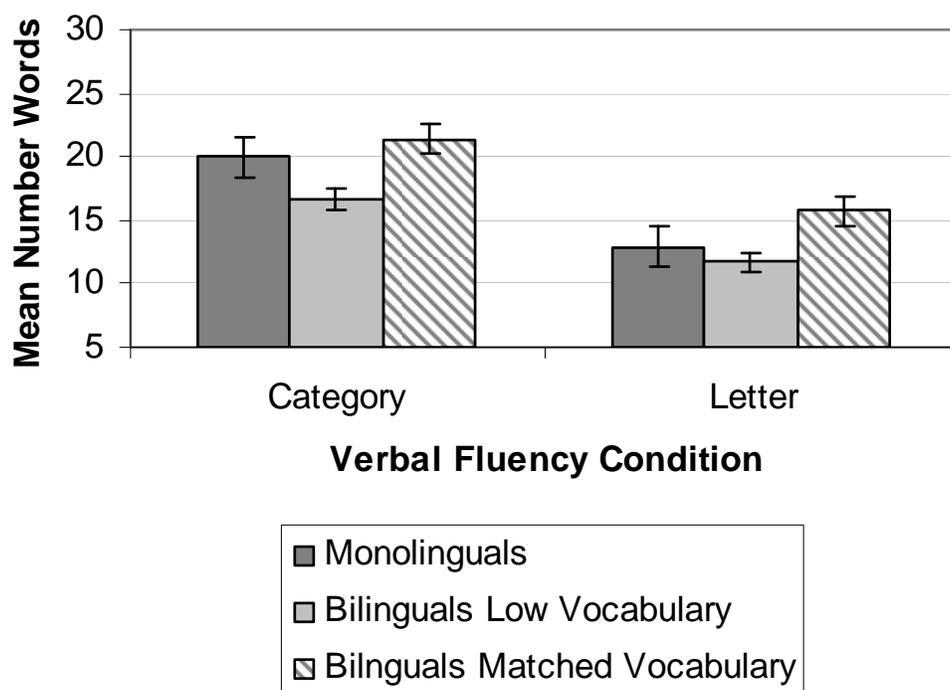


Fig. 3. Number of words generated on category-fluency and letter-fluency subtests of the verbal-fluency task for monolinguals, bilinguals with lower vocabulary, and bilinguals with vocabulary matched to monolinguals. From Bialystok, Craik, and Luk (2008b).

MECHANISM FOR THE BILINGUAL ADVANTAGE

It is well established that the representational systems for both languages of a well-practiced bilingual are active and potentially available when that individual is speaking in either language. Our suggestion is that the mechanism recruited to resolve the potential conflict from the two language systems and select appropriately from the target language is some domain-general aspect of executive control. The necessity to use this conflict management system continuously enhances its function, with consequent benefits to control in both language and nonlanguage tasks. One test of this hypothesis is to compare bilinguals for whom conflict is always present with those for whom conflict is less intrusive—for example speech-sign

bilinguals who can resolve the conflict by simply producing both languages simultaneously. In a study comparing monolinguals, bilinguals, and speech-sign bilinguals, advantages in executive control on a nonverbal flanker task were found only for the verbal bilinguals (Emmorey, Luk, Pyers, & Bialystok, 2008).

DOES BILINGUALISM PROTECT AGAINST COGNITIVE DECLINE?

In all the studies described here, participants were selected to be healthy and free from cognitive impairment. But aging sometimes includes challenges such as dementia. Given the sustained advantage of bilinguals into older age, does bilingualism continue to offer protection in such cases? A large body of research has pointed to the importance of “cognitive reserve,” the protection against cognitive decline that comes from active engagement in stimulating intellectual, social, and physical activities (Stern, 2002). To examine whether bilingualism contributes to cognitive reserve, we compared the age of onset of symptoms in 91 monolingual and 93 bilingual patients who had been diagnosed with dementia. With all else being equal, the age of dementia onset for the bilinguals was 4 years later than it was for the monolinguals—a highly significant difference (Bialystok, Craik, & Freedman, 2007). A four-year delay of symptoms of dementia is much greater than any effect associated with drugs and represents considerable savings in health care costs.

CONCLUSIONS

This body of research has converged on the conclusion that the experience of speaking two languages on a regular basis has broad implications for cognitive ability, enhancing executive-control functions across the lifespan. Ironically, the only recorded negative consequences of bilingualism are on verbal knowledge and skill—specifically, smaller vocabularies and less rapid access to lexical items. But this is easily outweighed by the evidence

supporting a range of advantages in the development, efficiency, and maintenance of executive functions. The finding that bilingualism defers the onset of dementia by 4 years, if confirmed by further studies, is a particularly dramatic benefit. The evidence at present thus shows that speaking more than one language does indeed appear to have a beneficial effect on aspects of cognitive control. This conclusion raises a number of questions. What about *three* languages? Is the trilingual advantage even greater? And does the relation between two languages make a difference? That is, does speaking two related languages, such as Spanish and Italian, give a greater (or lesser) advantage than speaking unrelated languages such as English and Chinese? Perhaps most intriguingly, what is the neural basis of the bilingual advantage? Are these performance differences mirrored in functional architecture or structural properties of the brain? Many questions remain for future studies.

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