



## Review

## Aging in two languages: Implications for public health

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## ARTICLE INFO

## Article history:

Received 1 December 2015

Received in revised form 3 March 2016

Accepted 14 March 2016

Available online 16 March 2016

## Keywords:

Alzheimer's disease  
Dementia  
Bilingualism  
Cognitive aging  
Cognitive reserve  
Neuroplasticity

## ABSTRACT

With the population aging and a dramatic increase in the number of senior citizens, public health systems will be increasingly burdened with the need to deal with the care and treatment of individuals with dementia. We review evidence demonstrating how a particular experience, bilingualism, has been shown to protect cognitive function in older age and delay onset of symptoms of dementia. This paper describes behavioral and brain studies that have compared monolingual and bilingual older adults on measures of cognitive function or brain structure and reviews evidence demonstrating a protective effect of bilingualism against symptoms of dementia. We conclude by presenting some data showing the potential savings in both human costs in terms of demented patients and economic considerations in terms of public money if symptoms of dementia could be postponed.

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The decline of cognitive function with adult aging and the risk of experiencing clinical impairment in the form of mild cognitive impairment (MCI) or Alzheimer's disease (AD) make understanding the process of cognitive decline and the search for remediation an urgent priority. The high prevalence of dementia (Graham et al., 1997; Plassman et al., 2007) in conjunction with the explosive growth in the number of senior citizens present enormous challenges to national economies and the management of health care. Any progress in rethinking the causes of cognitive decline and the creation of novel approaches to intervention would make a significant contribution to public health. This research, however, has

been dominated by biological models with insufficient regard for environmental and experiential factors. A more balanced view is needed for progress on these crucial issues.

There have been advances in understanding the biological basis of AD (Weiner et al., 2012) and developing pharmacological therapies (Zhu et al., 2013), but the effectiveness of these approaches remains limited. Massoud and Gauthier (2010) claim that the benefits of existing drugs for symptomatic treatments in dementia are modest, and some argue that the magnitude of this benefit, although statistically significant, is marginal at best and difficult to detect, measure, and quantify clinically (Hildreth and Church, 2015; Kadoszkiewicz et al., 2005; Raina et al., 2008). Yet, enabling people to function independently for longer has immediate social and economic benefit by adding quality of life to the patient and time during which health care resources are not required. Importantly, some environmental factors have been shown to maintain cognitive functioning with aging and postpone the onset of symptoms of dementia. These factors contribute to a concept called 'cognitive

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reserve' (Stern, 2002), and include education, occupational status, socio-economic class, and involvement in physical, intellectual and social activities (Stern et al., 1994; Bennett et al., 2003, 2006).

Research has shown that bilingualism is also a potent source of cognitive reserve, and a growing body of work has documented protective effects of bilingualism across the lifespan. The general finding is that bilinguals outperform monolinguals on tasks that require executive control or selective attention (review in Bialystok et al., 2009). More dramatically, bilingual individuals display symptoms of dementia significantly later than comparable monolinguals (e.g., Alladi et al., 2013; Bialystok et al., 2007; Woumans et al., 2015) and show significantly better cognitive recovery following stroke than monolinguals (Alladi et al., 2016). Thus, bilingualism is an experiential factor that has a substantial impact on cognitive aging.

Not all studies investigating the effect of bilingualism report these beneficial results. Paap and Greenberg (2013), for example, found no difference between monolingual and bilingual young adults performing simple executive function tasks and argued that such differences did not exist.<sup>1</sup> However, an earlier study by Bialystok et al. (2005) also showed no difference between monolingual and bilingual young adults but significantly better performance by bilinguals for groups of children, middle-aged, and older adults performing the same task, suggesting that because of ceiling effects, some tasks are not sufficiently sensitive to detect differences in young adults. But such variability is normal: Kramer and Erickson (2007) pointed to studies that failed to support the well-established benefit of exercise on cognitive function. Dissenting results are part of the evidence and need to be reconciled with positive findings, not used to overrule them (see Bak, 2016 for discussion).

To understand how bilingualism might protect against symptoms of dementia, consider cognitive changes in healthy aging. Aging is accompanied by stability in some cognitive functions and decline in others, with the age of onset of decline varying for different abilities. In language comprehension, for example, semantic processing of single words and discourse shows stability with aging when measured on-line but decline with aging when attentional control requirements are increased through use of off-line measures that require memory (for review, see Burke and Shafto, 2008). For memory, aging effects are minimal in simple verbal span tasks (e.g., digit span) but more pronounced for complex working memory tasks that require retention of information while other information is processed and interpreted (e.g., backward span; Bopp and Verhaeghen, 2005). Importantly, the typical account of this pattern of spared and impaired cognition is that it reflects the degree to which tasks require executive control; age-related declines are more evident for tasks requiring updating, switching and inhibiting attention (Braver and West, 2008; Engle, 2002; Hasher et al., 2007). These are precisely the processes for which bilinguals have been shown to excel. Moreover, poorer performance on such functions predicts progression to dementia (e.g., Clark et al., 2012).

Why does bilingualism affect executive control processes? The hypothesis is that unlike monolinguals, bilinguals are continually required to select the language they intend to use. Because both languages appear to be continually active even in strongly monolingual contexts, the process of selecting the intended

language recruits mechanisms that enable selection processes more generally (Kroll et al., 2014, 2015, for reviews). These selection mechanisms are part of the executive control system, so language selection may thus have generalized benefits for cognition. Older bilinguals, with many years of experience managing the two languages, therefore, might be expected to be skilled across different aspects of executive control, all of which are considered to be vulnerable with aging. Greater benefits are expected to accrue with more years of active bilingual experience.

The first study to report these consequences in healthy older bilinguals (Bialystok et al., 2004) used the Simon task to show that decline in executive control over the lifespan was modulated, with less decline for older bilinguals than for age-matched monolinguals. There were three experiments reported in this paper and in all cases the bilinguals had used both languages regularly since the age of 6 years, although the languages were different in each case. As in cognitive aging in general, the evidence for older bilinguals varies with several factors, but overall, there is strong support for a benefit for older bilinguals relative to their monolingual counterparts in both behavioral performance and brain function (Bialystok et al., 2009, 2012).

To illustrate, a study by Gold et al. (2013) used a non-linguistic switching task to determine whether younger and older healthy bilingual adults differed from age-matched monolinguals. They found better behavioral performance for the bilinguals in the older age group but no language group effects in the younger adults. Similarly, the researchers found little difference between young adult monolinguals and bilinguals in patterns of brain activation but significant evidence for more efficient brain function for bilinguals in the older adult group. The interpretation is that older bilinguals use relevant brain mechanisms more efficiently than monolinguals, but absence of such differences in younger adults may reflect ceiling performance on the simple task.

As in all cross-sectional research, there is a question about whether it is bilingualism that influences cognitive performance or whether individuals endowed with better cognitive abilities are more likely to learn foreign languages. A study by Vega-Mendoza and colleagues tested language students and literature students at the beginning of their university careers on executive control performance and found no differences between the groups. However, after 4 years of intensive study, language students outperformed literature students on a test of attentional switching—exactly the type of task in which we would expect an effect of bilingual language use (Vega-Mendoza et al., 2015). Similarly, Sullivan et al. (2014) measured performance on a no-go task conducted while electroencephalography was recorded at the beginning of the academic year for monolingual university students who then spent the year studying either Spanish or Psychology with no foreign language classes. Results at the end of the academic year showed similar behavioral performance for the two groups but more advanced electrophysiology for the Spanish students in terms of the N2/P3 waveform.

More compelling evidence for a causal role of bilingualism in improving cognitive performance comes from a study of the Lothian Birth Cohort (Bak et al., 2014). In 1947, all Scottish children born in 1936 (and therefore aged 11 years) underwent comprehensive intelligence testing. Around 60 years later, almost 1000 of those children from the Lothian area near Edinburgh could be traced and then re-assessed. The important finding was that individuals who learned a second language after the age of 11 achieved better cognitive results than would be predicted from their childhood performance, suggesting that language learning and use can mitigate the effects of cognitive aging, independent of childhood intelligence. The effects were largest for those whose intelligence scores were initially low. These results provide persuasive evidence for the direction of influence to be from bilingualism to cognition and not the reverse.

<sup>1</sup> An observation in recent studies is that even when a global difference between bilinguals and monolinguals is not found for young adults, there may nonetheless be systematic differences in the way that bilinguals exploit cognitive resources to perform particular tasks (e.g., Morales et al., 2013). These are not simple effects but interactions that reflect a complex engagement of cognitive mechanisms and the neural networks that support them.

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