Ageing Research Reviews 27 (2016) 56–60

Contents lists available at ScienceDirect

Ageing Research Reviews

journal homepage: www.elsevier.com/locate/arr

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; Kaduszkiewicz 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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http://dx.doi.org/10.1016/j.arr.2016.03.003
1568-1637/

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.[1] 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.

[1] 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.

Similar patterns can be found by studying brain structure and function. Since bilingualism naturally increases the cognitive load in executive processing (Abutalebi and Green, 2007), it is plausible to expect to observe neural plasticity, specifically in areas related to executive control. Such neuroplastic changes are best expressed as adaptive effects in the neural regions and circuits that mediate the specific demands of bilingual language processing and thus should be absent in the monolingual brain (Green and Abutalebi, 2013). It is also plausible to expect neuroanatomical changes in brain regions associated with language learning (Li et al., 2014). The rationale for these suppositions is that bilingualism *per se* stimulates certain brain areas, resulting in neural reserve that may eventually protect the aging brain against atrophy.

These predictions have largely been supported. Correlations between increases in L2 proficiency and enhanced brain structure have been found for the left prefrontal cortex (Stein et al., 2012), inferior parietal lobule (Mechelli et al., 2004) and temporal poles (Abutalebi et al., 2014), all regions concerned with executive control. Similarly, increased grey matter density of the anterior cingulate cortex, a neural structure involved in monitoring actions and detecting errors, correlated with better conflict monitoring in bilinguals but not in their monolingual counterparts (Abutalebi et al., 2012). Increased grey matter densities in bilinguals compared to monolinguals have been reported in regions of the basal ganglia (Zou et al., 2012) and left putamen (Abutalebi et al., 2013). These studies clearly support the view that neuroplastic changes take place in the bilingual brain primarily in areas related to executive control and language learning. Such findings may constitute the neural basis of the cognitive advantages in executive control found for bilinguals in behavioral studies (Li et al., 2015; for review).

Two possible mechanisms for this protection have been proposed—neural reserve and neural compensation (Perani and Abutalebi, 2015). Following the notion of neural reserve, lifelong practice with executive functions entails structural changes in the brain, namely, increased grey and white matter densities in brain regions associated with executive control that eventually render the bilingual brain more resistant to brain atrophy or disease pathology. In contrast, neural compensation acts as a mechanism to clinically overcome loss of brain structure such as brain atrophy in aging or neurodegeneration in diseases by recruiting more intact regions to compensate for more vulnerable regions. Evidence in support of the role of neural compensation was provided by Schweizer et al. (2012) who studied monolingual and bilingual individuals with AD, matched on age, occupational status, cognitive performance and education. Bilinguals had used two languages regularly since childhood, with a variety of languages being included in the group. The results showed significantly greater medial temporal lobe atrophy in bilinguals using linear measurements derived from CT scans. In other words, despite having greater medial temporal lobe atrophy, the bilingual individuals with AD performed in the same manner on neuropsychological testing as their monolinguals peers with less brain atrophy, hence, compensating for the greater atrophy.

The most consistent results showing protective effects of bilingualism come from retrospective studies in which monolingual and bilingual patients who have been diagnosed with dementia are compared for age of symptom onset. These studies have reported a 4–5 year delay for bilinguals from different populations, such as Canada (Bialystok et al., 2007), India (Alladi et al., 2013), U.S.A. (Gollan et al., 2011), and Belgium (Woumans et al., 2015). The studied cohorts included migrants as well as non-migrants, educated as well as illiterate people, high as well as low socio-economic background, and early as well as late bilinguals. In addition to these factors, the patterns of language use varied across these studies, from predominantly monolingual societies in Toronto and Ghent to a highly multilingual population of Hyderabad, characterized by frequent language switching and mixing (see Freedman et al., 2014 for discussion).

In this research, greater benefit was found for less educated groups than well-educated ones (Alladi et al., 2013; Chertkow et al., 2010; Gollan et al., 2011). In the Indian cohort, the effects of education disappeared when performance was controlled for bilingualism, but the effects of bilingualism remained significant after controlling for education (Bak and Alladi, 2016; Iyer et al., 2014). This increased benefit for those with less education is similar to the results reported in the cognitive measures examined in the Lothian Birth Cohort study (Bak et al., 2014).

Another approach to this question is the use of incidence studies that examine the onset of dementia in cohorts over time. Wilson et al. (2015) followed a cohort of approximately 1000 individuals over about 6 years. During this time, about 40% of participants developed MCI, but the risk was significantly lower in bilingual participants. Similarly, Perquin et al. (2013) examined 232 healthy older adults in Luxembourg and found that 19% of them met criteria for MCI. None of the individuals in the Luxembourg sample was monolingual, but the protection against MCI significantly increased with the number of languages spoken.

In contrast to these results, an incidence study from New York failed to find a significant protective effect of bilingualism (Zahodne et al., 2014). Nonetheless, the incidence of MCI was lower in bilinguals than monolinguals, bilinguals were older at the time of diagnosis, and bilinguals outperformed monolinguals on the executive control tasks. It is possible that bilingualism was not significant because of design issues, such as including age in the same model as bilingualism; all else being equal, older individuals are more likely to become demented than younger individuals and this difference was not controlled. An earlier study by the same group also reported no protection from education, a well-known source of cognitive reserve (Zahodne et al., 2011), possibly because of similar design details. Moreover, bilingualism was defined differently in the Zahodne et al. (2014) study than in most research: the monolinguals were Spanish-speakers who had lived in New York City for about 50 years, blurring the distinction between monolinguals and bilinguals in this community. Definitions of bilingual are central to this research but are rarely discussed.[2] Overall, the studies present strong support for the role of bilingualism in protecting cognitive function with aging.

As the population ages, the most pressing issue for public health is the availability of resources to maintain adequate care for seniors, but the nature of these services depends on the context. In Hong Kong, for example, natives generally have Cantonese as their first language and may acquire English in school. English is then widely used during schooling and in their professional lives, leading to somewhat equivalent use of Cantonese and English. However, once these individuals retire they use English less than Cantonese. Abutalebi and colleagues (Abutalebi et al., 2015, 2014) reported that in this aging population, only those who maintained high usage of a second language showed neuroprotective effects in terms of increased grey matter in certain brain areas that may eventually protect against cognitive decline. If we are to profit from the protective effects that bilingualism provides, governments and health systems should activate social programs and interventions

[2] Individuals are typically considered bilingual if they use two or more languages actively. Bilinguals differ with respect to their level of proficiency in the two languages, the degree to which one language is more dominant, was acquired early or late in life, whether the two languages are used in the same or different contexts, and whether one of the languages is a minority language. Each of these factors may potentially impact the consequences of bilingualism (see Luk and Bialystok, 2013 for a discussion).

to support the maintenance of the second language among senior citizens.

There are also financial costs associated with these issues. In the United States, data from about 10 years ago reported that seniors made up about 13% of the population but consumed 36% of personal health care expenses (Agency for Healthcare Research and Quality, 2006). In Canada, a similar report stated that seniors accounted for less than 15% of the population but consumed 45% of health care expenditures (Canadian Institute for Health Information, 2014). A report from the National Institutes for Health (2013) claimed that in 2010 alone, the cost of treating dementia in the U.S., including nursing homes, medication, and physician care, was $215 billion.

These figures underline the urgency of the problem. Ultimately, the best solution is to find effective biological or pharmaceutical interventions that can directly address the disease with the goal of curing, and more optimistically, preventing it. But such a solution seems a long way off. What is immediately available is a set of environmental solutions to reduce the risk or mitigate the effects of the disease. Thus, the lifestyle factors that contribute to cognitive reserve become part of the arsenal against dementia, with more powerful impact than any known drug. Societies have a role to play in supporting and maintaining bilingualism in older adults and in nurturing bilingualism in children and young adults through education.

In a recent article in the *New York Times*, Newt Gingrich (2015) expressed concern for the problem of rising numbers of dementia patients in our aging population and argued that the National Institutes of Health should double its budget devoted to research on dementia in an attempt to hasten a solution. He wrote, “Delaying the average onset of the disease by just five years would reduce the number of Americans with Alzheimer’s in 2050 by 42 percent, and cut costs by a third.” These dramatic claims are consistent with scientific evidence: Brookmeyer et al. (2007) used epidemiological data from 2006 to predict the prevalence of Alzheimer’s disease in 2050. Their model projected public health savings that would accrue from only a one year delay in symptom onset and showed a staggering 9.2 million fewer cases of the disease. In this context, Gingrich’s projection for public savings based on a five-year delay is completely reasonable, and a five-year delay is almost exactly what has been found for bilingualism. A solution may be hiding in plain view.

Acknowledgments

We thank Merel Keijzer for bringing us together at a workshop on Bilingualism and Cognitive Aging that she helped organize at the University of Groningen in 2015. The meeting gave us the opportunity to begin a discussion that resulted in this paper.

Preparation of this manuscript was supported by Grant A2559 from the Natural Sciences and Engineering Research Council and Grant R21AG048431 from NIH to E. Bialystok; Grants BCS-1535124 and OISE-0968369 from the US National Science Foundation and Grant R21HD082796 from NIH to J.F. Kroll; a Sontag grant from Pomona College to D. Burke; Grant from the CRC project University of Bolzano to J. Abutalebi.

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