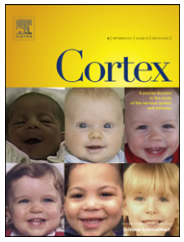
CORTEX 48 (2012) 991–996

Available online at www.sciencedirect.com

SciVerse ScienceDirect

Journal homepage: www.elsevier.com/locate/cortex



Research report

Bilingualism as a contributor to cognitive reserve: Evidence from brain atrophy in Alzheimer's disease

Tom A. Schweizer [a,b,c,*], Jenna Ware [b], Corinne E. Fischer [a,d], Fergus I.M. Craik [e,f] and Ellen Bialystok [e,g]

[a] Keenan Research Centre of the Li Ka Shing Knowledge Institute at St. Michael's Hospital, Toronto, Canada
[b] Division of Neurosurgery, St. Michael's Hospital, Toronto, Canada
[c] Faculty of Medicine, Department of Surgery, University of Toronto, Canada
[d] Faculty of Medicine, Department of Psychiatry, University of Toronto, Canada
[e] Rotman Research Institute at Baycrest, Toronto, Canada
[f] Department of Psychology, University of Toronto, Canada
[g] Department of Psychology, York University, Canada

ARTICLE INFO

Article history:
Received 1 October 2010
Revised 8 December 2010
Accepted 12 April 2011
Action editor Stefano Cappa
Published online 27 April 2011

Keywords:
Alzheimer's disease
Bilingualism
Cognitive reserve
Atrophy
Medial-temporal lobes

ABSTRACT

Much of the research on delaying the onset of symptoms of Alzheimer's disease (AD) has focused on pharmacotherapy, but environmental factors have also been acknowledged to play a significant role. Bilingualism may be one factor contributing to 'cognitive reserve' (CR) and therefore to a delay in symptom onset. If bilingualism is protective, then the brains of bilinguals should show greater atrophy in relevant areas, since their enhanced CR enables them to function at a higher level than would be predicted from their level of disease. We analyzed a number of linear measurements of brain atrophy from the computed tomography (CT) scans of monolingual and bilingual patients diagnosed with probable AD who were matched on level of cognitive performance and years of education. Bilingual patients with AD exhibited substantially greater amounts of brain atrophy than monolingual patients in areas traditionally used to distinguish AD patients from healthy controls, specifically, the radial width of the temporal horn and the temporal horn ratio. Other measures of brain atrophy were comparable for the two groups. Bilingualism appears to contribute to increased CR, thereby delaying the onset of AD and requiring the presence of greater amounts of neuropathology before the disease is manifest.

1. Introduction

In the course of diagnosing patients with Alzheimer's disease (AD) and other forms of neurodegenerative disorders, clinicians often encounter individuals with substantial levels of brain atrophy but with relatively spared cognitive functioning. A recent review found that approximately 30% of individuals who exceed pathological criteria for AD at autopsy had shown no signs of cognitive impairment during life (Valenzuela and Sachdev, 2006). This mismatch between degree of brain

* *Corresponding author*. Department of Surgery, Division of Neurosurgery, St. Michael's Hospital, 30 Bond Street, Toronto, ON M5B 1W8, Canada.
E-mail address: SchweizerT@smh.toronto.on.ca (T.A. Schweizer).
0010-9452/$ – see front matter © 2011 Elsevier Srl. All rights reserved.
http://dx.doi.org/10.1016/j.cortex.2011.04.009

atrophy and level of cognitive functioning has been attributed to the concepts of 'brain reserve' and 'cognitive reserve' (CR) (Stern, 2002, 2009), although the nature of these constructs is still poorly understood. Cases of brain reserve are thought to involve individuals whose greater reserve capacity reflects some structural features of the brain itself; suggested characteristics include greater brain size, increased number of neurons, and larger pyramidal neurons (Sachdev and Valenzuela, 2009; Valenzuela and Sachdev, 2006). CR, in contrast, emphasizes functional rather than structural benefits associated with a variety of intellectual, social and physical activities in a person's daily life. Thus, a large number of studies have now documented the beneficial effects of education, occupation and stimulating leisure activities in reducing or delaying the incidence of AD and other forms of dementia (Fratiglioni et al., 2004; Sachdev and Valenzuela, 2009; Stern, 2009; Valenzuela and Sachdev, 2006). One limitation on the usefulness of the concept of CR, however, is its correlational nature. It is often unclear whether individuals with high levels of attainment in education or occupation who show evidence of CR do so because their brains are genetically well endowed, thereby enabling them to succeed, or whether their elevated levels of CR are caused more directly by heightened levels of intellectual and social engagement.

The constant use of two languages over the lifespan is one type of mental activity that may also contribute to CR; if so, it is difficult to argue that some inherited brain characteristic leads a person to become bilingual. Rather, bilingualism occurs in the great majority of cases in response to such circumstances as emigration to a different country, differences between the family language and the language of school or workplace, and the need to communicate with neighboring groups (Diamond, 2010). Bilingualism thus seems a clear case of an environmental factor that acts to produce CR, although of course this environmental factor may well also affect the brain, its development and organization and contribute to brain reserve.

What is the evidence that bilingualism has an effect on mental functioning? Bialystok and colleagues have reported that bilingualism in children (Bialystok, 2001) and adults (Bialystok et al., 2004, 2006) enhances specific skills associated with cognitive and attentional control. The constant necessity to resist attending to a second language in favor of the one in use, and the need to switch between languages demands more effortful attention than does monolingual speech production, and this greater cognitive demand fosters the development of a higher level of attentional control (reviewed in Bialystok et al., 2009). These results prompted the question of whether such highly practiced and developed skills in bilinguals might have some neuroprotective function in older adults in the context of dementia. Preliminary evidence in favor of this outcome was reported in a study by Bialystok et al. (2007). They recorded the ages at which symptoms of dementia appeared in 184 patients, half of whom were bilingual, and reported a delay of over 4 years in the onset of symptoms in the bilinguals relative to the monolinguals. Cognitive level and other lifestyle variables were comparable, so the authors concluded that the bilingual group benefited from protection as a result of their lifelong experience in using two languages. These findings were subsequently replicated in a new study of 211 patients, all diagnosed with probable AD and half of whom were bilingual (Craik et al., 2010). Similar results were reported by Chertkow et al. (2010) who studied a sample of 632 patients who were diagnosed with probable AD and found a delay of almost 5 years in the diagnosis of AD in bilingual patients, although this result was found only in an immigrant group. However, a significant protective effect was found more generally in patients who spoke three or more languages. Thus, the conclusion that bilingualism (or multilingualism) is associated with a very significant delay (4–5 years) in the onset of symptoms of AD is well documented in total samples of over 1000 patients.

The relation between brain pathology and cognitive functioning in the context of CR may be demonstrated in two major ways. First, if two groups, one with high and the other with low levels of CR are matched on degree of brain pathology, then the high CR group should show higher levels of cognitive functioning – their greater CR is protective and confers an advantage. The second approach is to match the two groups on cognitive level or on level of clinical severity, with the prediction that the high CR group should exhibit greater amounts of AD pathology. Again, the logic is that the group's higher levels of CR compensates for the advanced pathology, enabling them to function at a higher level than the pathology would normally predict. This second approach was one of the earliest methods used to test the CR hypothesis (Stern, 2009), and was also the method adopted in the present report.

In a series of studies in the 1990s, Stern and colleagues used resting regional cerebral blood flow (rCBF) as a surrogate measure of degree of AD pathology. This assumption was based on previous work showing that rCBF values are related to the underlying pathology; blood flow decreases as pathology increases. Using this logic with patients matched for clinical severity of AD (based on cognitive and functional measures) the investigators found negative correlations between years of education and resting rCBF levels in areas of the brain associated with AD. That is, more education was associated with reduced blood flow and higher levels of pathology. Parallel findings were obtained for occupation and engagement in leisure activities (reviewed in Stern, 2009). A similar approach was taken by Kidron et al. (1997); they found that individuals with more education showed more ventricular enlargement in the parietal region, indicating more atrophy. Thus it appears that more education allows individuals to function at a higher level than their degree of atrophy would predict. In the present study we measured brain atrophy directly with computed tomography (CT), with the prediction that bilingual patients, matched on cognitive level and clinical severity with monolingual patients, would show greater atrophy in brain regions associated with AD pathology.

As described below, we selected two groups of patients, one of monolinguals and the other of bilinguals, who had been diagnosed with probable AD, and who had received CT as part of the diagnostic process. Crucially, the groups were matched on level of cognitive functioning and also on degree of clinical severity. Pathological changes occur early in the disease process, with preferential atrophy observed in the Medial-Temporal Lobes (MTL). Several studies have identified measures derived from CT that best characterize MTL atrophy. Zhang et al. (2008) analyzed the CT images of 248 dementia patients and 59 controls using a series of ratio scores based on linear measurements that assessed global, local, cortical and