Short Report

Does multilingualism affect the incidence of Alzheimer's disease?: A worldwide analysis by country

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ABSTRACT

It has been suggested that the cognitive requirements associated with bi- and multilingual processing provide a form of mental exercise that, through increases in cognitive reserve and brain fitness, may delay the symptoms of cognitive failure associated with Alzheimer's disease and other forms of dementia. We collected data on a country-by-country basis that might shed light on this suggestion. Using the best available evidence we could find, the somewhat mixed results we obtained provide tentative support for the protective benefits of multilingualism against cognitive decline. But more importantly, this study exposes a critical issue, which is the need for more comprehensive and more appropriate data on the subject.

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Introduction

An exciting idea that has emerged in contemporary cognitive and clinical neuroscience is the possibility that certain everyday activities may provide some protection against assaults to the central nervous system. Whether in the form of head injuries, stroke, disease, or normal aging processes, a ubiquitous consequence of these assaults is a decline in cognitive function. The rationale for this protection against cognitive decline is based on the overlapping concepts of cognitive reserve and brain fitness (e.g., see Stern, 2002). Some activities exercise the mind's organ–that is, the brain–in such a way that it increases the brain's fitness. Consequently, when this organ is assaulted, its increased fitness allows it to better overcome, or compensate for, the ensuing damage. Activities that have been proposed to generate cognitive reserve and increase brain fitness include attending formal schooling (Stern et al., 1994), playing a musical instrument (Hanna-Pladdy & MacKay, 2011), playing certain video-games (Bavelier, Green, Pouget, & Schrater, 2012), and being bilingual (Bialystok, Craik, & Freedman, 2007). The potential benefits of these activities have been shown to be considerable. For example in a thorough meta-analytic review, Valenzuela & Sachdev (2006) concluded that higher levels of education, occupational complexity, and regular engagement in mentally stimulating leisure activities are associated with a 50% reduction in the incidence of dementia. In the same vein, our focus here is to explore the association between one form of assault to the mind, senile dementia caused

primarily by Alzheimer's disease, and one form of mental exercise, multilingualism.

It is widely assumed that multilingual individuals (bilinguals inclusive) must regularly monitor their environment for cues to determine which language should be active for the purposes of production and comprehension. They must then select the appropriate language and inhibit the unwanted ones accordingly. Monitoring, selecting, and inhibiting are cognitive processes subsumed under the umbrella of executive functions. Under the assumption that these executive functions receive greater exercise in the bilingual mind than in the monolingual mind, it has been proposed that bilingualism affords advantages in executive cognitive control that generalize beyond the linguistic domain, particularly when exposure to multiple linguistic contexts occurs early on in cognitive development (e.g., Bialystok et al., 2004; but see Paap and Greenberg (2013), for some arguments to the contrary). Such advantages in performance have been frequently reported using non-linguistic tasks of executive function. However, the landscape of published evidence[1] for a bilingual advantage is, at best, mixed (for reviews, see Adesope, Lavin, Thompson, & Ungerleider, 2010; Hilchey & Klein, 2011; Hilchey, Saint-Aubin, & Klein, 2015; Klein, 2015; Paap, Johnson, & Sawi, 2015; Valian, 2015).

Similarly, the evidence suggesting an association between bilingualism and a delay in the onset of Alzheimer's disease (AD)

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[1] The corpus of published work on this topic has recently been characterized as biased in favour of reporting bilingual advantages (de Bruin, Treccani, & Della Sala, 2014)

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and other forms of dementia is also mixed. In the first study exploring this relation, Bialystok et al. (2007) divided a sample of 184 patients with dementia (most of whom were diagnosed with probable AD) into two roughly equal groups of lifelong bilinguals and monolinguals. They found that the age at which these patients first reported symptoms of dementia was 71.4 for the monolinguals and 75.4 for the bilinguals (formal diagnoses of dementia were 3–4 years later for both groups). In a follow-up study, Craik, Bialystok, and Freedman (2010) found an even larger delay (5.1 years) in symptom onset in the bilingual sample. Whereas other publications offer some support for this pattern (e.g., Alladi et al., 2013; for a review see Freedman et al., 2014), they often include qualifications. For example, Chertkow et al. (2010) did not find a protective advantage of bilingualism when analyzing their entire sample, but they did find one when they restricted their sample to immigrants to Canada. At the same time, they found an advantage in individuals who spoke 4 or more languages in their overall sample. Gollan, Salmon, Montoya, and Galasko (2011) also found a beneficial effect of bilingualism, but this effect was restricted to a less-educated sub-group of the full sample. On the other hand, large scale studies by Crane et al. (2009, 2010); Sanders, Hall, Katz, and Lipton (2012); Yeung, St. John, Menec and Tyas (2014) and Zahodne, Schofield, Farrell, Stern, and Manly (2013) have reported null results. In a comprehensive review of bilingualism and cognition, Valian (2015) points out that this disagreement has a methodological parallel: all of the studies that found positive evidence were retrospective while those reporting null results were prospective. Importantly, the retrospective studies in question suffer from what Valian refers to as the complement class problem: "Many individuals with cognitive difficulties never appear at a memory clinic and their characteristics are unknown; similarly, individuals without cognitive difficulties seldom appear at a memory clinic. Those individuals comprise the complement class. We only know the size and composition of the class that has visited the clinic, a class that may or may not be representative of the general population." Consequently, it is generally agreed that the prospective methodology, which follows a relatively unselected, random sample over time, is superior (which lends support to the idea of a null relation between bilingualism and the onset of dementia).

The question

This report was inspired by a comment made at the end of the paper by Craik et al. (2010). After summarizing the findings from their retrospective study that bilingualism was associated with a delay in the onset of dementia, they concluded that "[t]he effects of this factor on the prevalence of AD in countries with high rates of bilingualism remain to be assessed". Rephrased as a question, would country-by-country data on these two variables provide evidence for or against the proposition that multilingualism may delay the onset of symptoms of dementia? Conversely, does being monolingual serve as a "risk factor" for earlier onset of dementia? Our purpose in the present study is to do the best job possible, given the data we could find, to answer this question.

The approach

This paper is as much about how we need better data to generate a more confident answer to this question, as it is about answering it. Unfortunately, there is no consistent set of global data on either the degree of monolingualism or the age of onset of AD

symptoms per country. For present purposes, we decided to use what we believed were reasonable proxies for these two factors. A 5-year old unpublished manuscript by Parkvall (2009); (which can be obtained by e-mailing: parkvall@ling.su.se) provides his best estimate of the mean number of languages (m#L) spoken by the residents of a wide range of countries. This variable from Parkvall's manuscript will serve as a proxy for the frequency of monolingualism (with which multilingualism must be inversely related). Data for the incidence of Alzheimer's disease (iAD) was taken from an internet source that attributes the figures to a World Health Organization (WHO) report. This is not the same as the age of onset of symptoms. All other things being equal, however, on a country-by-country basis, a delay in the onset of AD will necessarily decrease the incidence of AD because more individuals will die before disease onset (or its detection). Of course, there are a variety of variables that might not be "equal" (life expectancy; health-care budgets, etc.). That noted, so long as the contributions of such factors are minimal or taken into consideration, then to the extent that the age of onset in a country is delayed because its residents are primarily multilingual, the reported incidence should also be lower. Thus, iAD will serve as a proxy for age of onset (with which iAD must be inversely related). The Craik et al. proposal that multilingualism delays the onset of the symptoms of dementia predicts that the correlation between these two measures should be negative.

Methods

Data on the mean number of languages spoken by the average resident of each country under investigation were taken from Parkvall (2009). Parkvall derived his data from (1) answers to a relevant question asked in each country's respective census (n=16); (2) semi-official surveys carried out in 2000 and 2002 on the member countries of the European Union (n=23); (3) figures derived from questionnaire data reported in the extant literature (n=18); (4) the 2001 New Zealand census, which included relevant statistics on persons born abroad[2] (n=30); (5) www.afrobarometer.org (2008; n=9); and (6) a combination of these and other sources (n=19). Among the many issues addressed by Parkvall (2009) measuring proficiency was a principal concern. For practical reasons, he decided to accept whatever definition of "speaking language X" the surveys from which he derived his figures had used.

Data on the incidence of Alzheimer's disease (death rate from AD/100,000) were taken from the website http://web.archive.org/web/20150323104104/http://www.worldlifeexpectancy.com/cause-of-death/alzheimers-dementia/by-country/ which, in turn, attributed the data to a 2011 WHO report. In addition to these two key factors, data on the population of each country, wealth (gross national income, or GNI) per capita, percentage of government funds spent on health care, percentage of adult literacy, and national life expectancy were taken from the United Nations databases (found in statistical tables #1 and #9 of the UNICEF report "The State of the World's Children 2009"; http://web.archive.org/web/20150323103737/http://www.unicef.org/sowc09/statistics/tables.php.

Before presenting our results it is worth noting, particularly in light of the different conclusions that have been reached so far by group studies using retrospective and prospective methods, that

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[2] Parkvall (2009) noted that these data were indirect and that immigrants to New Zealand might not be representative of their home countries. He adds, however, that …for several of these immigrant groups, there is data for their respective countries of origin, and the immigrants to New Zealand provide, if not a perfect, at least a good match (the margin of error being 30%, only in extreme cases, and usually considerably less).
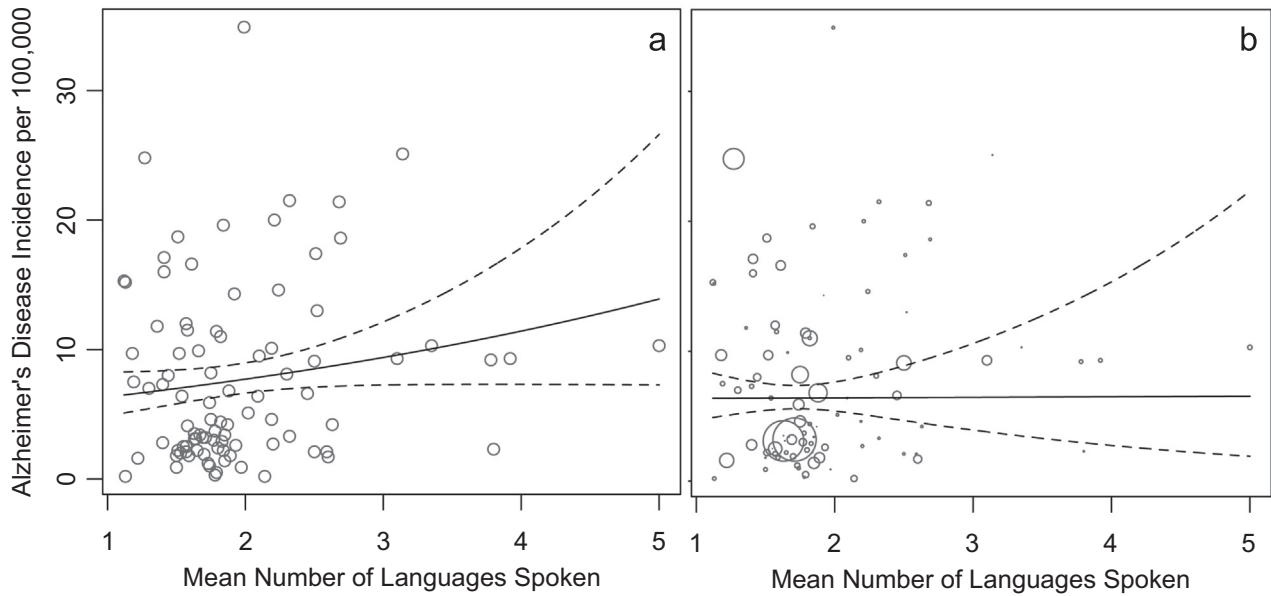
Fig. 1. (a) Scatterplot showing, for each of 93 countries, the incidence of Alzheimer's disease as a function of the average number of languages spoken by people in each country. (b) The same scatterplot with size of the symbols reflecting population of each country and the best fitting linear function (see text for explanation).

our population-based study is essentially about the correlation of incidence rates. It is certainly not prospective and while it uses retrospective data on the two key variables, it is not subject to the "complement class" problem that, as outlined by Valian (2015), challenges classical retrospective studies.

Results

There were 93 countries for which data on both m#L and iAD were available from the sources mentioned in the methods. A scatterplot showing the results from this relatively large sample of countries is presented in Fig. 1a. This initial analysis revealed a weak ($r_{91} = 0.134$), non-significant, *positive* correlation between m#L and iAD. Although the direction of this raw correlation is opposite to that predicted by the proposal we are exploring, it is important to note that when the data from each country are weighted by population,[3] the correlation becomes 0. Moreover, a linear function provides a relatively poor fit to these data ($r = 0.00$; Fig. 1b). In an analysis using generalized additive modelling with a beta family regression, 11.4% of the deviance is explained and the AIC score is reduced by 6 over a linear beta model (see Fig. 2). When the range of m#L is restricted from 1 to 2, our confidence in the relationship (illustrated in Fig. 2) increases. The result of this manipulation provides support for the proposal we are exploring. Importantly, when the m#L is close to 1, a country is primarily monolingual, and when the m#L is close to 2, there is likely a high degree of bilingualism. Thus, the shape of the function in this range implies that the incidence of Alzheimer's disease declines with increasing bilingualism. Although the function rises slightly beyond a m#L of 2, given the relatively small populations and overall paucity of the data points in this range, our confidence in
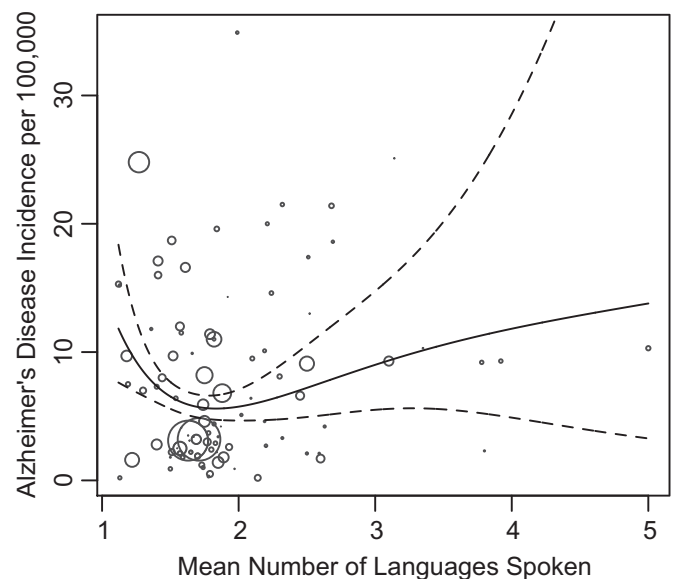
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[3] Our goal is to determine if there is a relation between the incidence of AD and the # of languages spoken. If we had individual data on these factors, then each individual would be counted separately and the data would naturally be weighted by equally by individual. What we do have is a total number of people in a country, the average number of languages spoken in that country, and the rate of AD. Given the aforementioned goal it is necessary to weight the data by the size of the country.
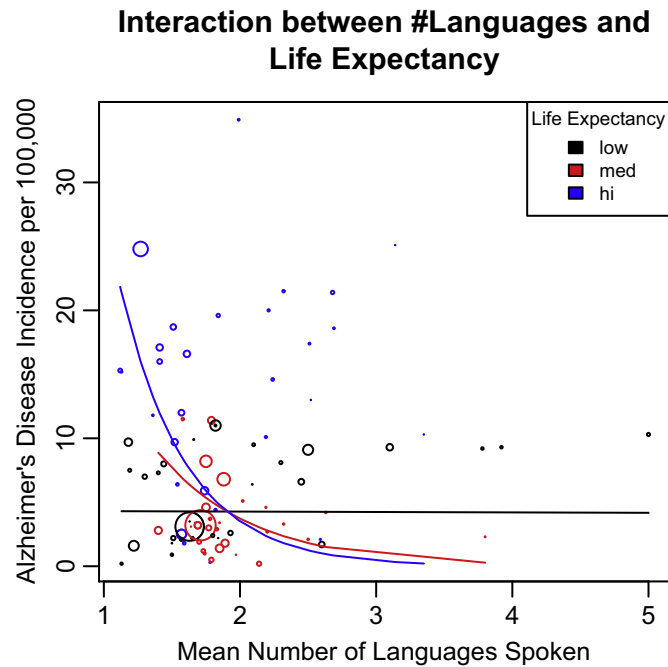

Fig. 2. An exploratory generalized additive model of the influence of mean number of languages spoken on incidence of AD.

this section of the function is low.

A factor that may modify or constrain the proposed relation between multilingualism and AD is life expectancy. In countries where life expectancy is relatively low, there will be reduced opportunity for the population to develop AD. When the relation between m#L and iAD was explored across life expectancy, an interaction was found. This interaction is illustrated by Fig. 3. As life expectancy increases, the slope of the relations between iAD and m#L moves from slightly positive at the lower life expectancies to negative at the higher ones. In accordance with the Craik et al. (2010) proposal, the relation between multilingualism and AD is strongly negative for the countries with the high life expectancy. It must be noted that this relation depends critically on weighting the data points by the population of each country.

There were 58 countries for which we had iAD data and for which the UN database provided information about the rate of

Interaction between #Languages and Life Expectancy

Fig. 3. The interaction between life expectancy and m#L. Life expectancy is represented by colour using low (42–66 years), medium (69–76) and high (77–83) to give an impression of the shape of the interaction. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

adult literacy. When these variables were simply correlated (see the Appendix for a table of simple correlations among all the measures mentioned in Methods section), a significant negative relation ($r_{56}=-0.27$, $p<0.05$) was obtained, suggesting that countries with a higher rate of adult literacy had a lower incidence of AD. When this correlation was recomputed weighting the countries by their populations, however, the correlation remained negative but was no longer reliable ($r=-0.16$). This is an instance where it would certainly be useful to have more data on literacy to increase our confidence in this potentially interesting relationship.

Both average wealth and government spending on health care were also examined. Unfortunately wealth (measured by GNI) is so highly correlated with life expectancy ($r=0.645$) that it is difficult to distinguish between the two in a model. Nevertheless, we believe that life expectancy is the more important factor based on the previously stated logical considerations. Government spending on health care had a relatively lower correlation with both life expectancy (0.396) and iAD (0.236).

Discussion

Using the proxy variables described above (mean number of languages spoken by a country's inhabitants and the incidence of AD) we found that there was considerable evidence for lower rates of senile dementia as the mean number of languages spoken increases from one to two. This finding supports the proposal that bilingualism may provide an increase in cognitive reserve and fitness that is thought to protect against AD. That said, any conclusions that might be drawn from the aforementioned analyses must be regarded with great caution. The most obvious weakness is that we have used proxies for the target variables. It is certainly possible that the results could be more or less in favour of the proposal if there were world-wide data from a large number of countries on the actual target variables.

A second consideration is that when a relationship between

two variables is considered to be substantial enough to warrant our attention, it does not necessarily entail a causal relationship between these variables. Some researchers (e.g., Morton & Harper, 2009; Hilchey & Klein, 2011) who have been concerned about the claim that bilingualism might enhance executive control have suggested that the possible contributions of other "hidden" factors (including socioeconomic status) may have mediated the positive evidence for this claim, and that negative evidence may be found in studies that are not so compromised (but may fail to be published, as suggested by de Bruin et al., 2014).

All this noted, the most important conclusion we can draw from the efforts described here is that more comprehensive and more appropriate data is needed to thoroughly evaluate the relationship between multilingualism and protection against cognitive decline. Because of the importance of the question put forth by the title of this paper, we strongly recommend that, after consultation with the appropriate experts, a worldwide group –such as the World Health Organization– collect this data and make it available to scientists, policy makers, and the general public.

Appendix

Simple correlations (in the cells above the negative diagonal) among some of the measures collected from the sources described in the methods section (numbers below the diagonal are the number of countries contributing to each corresponding correlation). (GNI=gross national income; LExp=life expectancy; LIT=rate of adult literacy; GH$=% of government funding spent on health).

	iAD	m#L	GNI	LExp	LIT	GH$
iAD		0.134	0.627	0.280	−0.274	0.236
m#L	93		0.073	−0.137	−0.224	0.005
GNI	90	90		0.645	0.448	0.391
LExp	88	88	88		0.649	0.396
LIT	58	58	58	58		0.430
GH$	76	76	76	76	50	

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