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Does bilingualism protect against cognitive aging?:

Methodological issues in research on bilingualism, cognitive reserve, and dementia incidence

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Abstract

Recent studies of bilingualism as a protective factor in cognitive aging have reported conflicting findings, and researchers have begun to explore the methodological complications that may explain differences across studies. This article details the current research landscape and addresses several issues relevant to the study of bilingualism and late-life cognitive function: study design, establishing causal relationships, confounding factors, operationalizing bilingualism, predicting cognitive level versus cognitive change, and incorporating brain structural variables to interrogate cognitive reserve.

Keywords

Cognitive aging trajectories; bilingualism and dementia; cognitive reserve

1. Introduction

Alzheimer's disease (AD), which is characterized by progressive memory loss and debilitating functional decline, is the most common type of dementia. Risk for AD is associated with genetic factors, vascular disease, and lifestyle factors, while higher levels of education, greater occupational complexity, and other cognitively-stimulating activities are protective against AD (Stern, 2012). Recent studies have investigated whether the cognitive demands of bilingualism, which involve attention and cognitive control, might similarly protect against AD. Indeed, bilingualism has been associated with better performance on executive function tasks that involve inhibition (Bialystok, Craik, Klein, & Viswanathan, 2004; Kovács & Mehler, 2009). Therefore, it is possible that bilingualism helps maintain cognitive function in the face of age-related neuropathology, thus postponing the onset of dementia (Craik, Bialystok, & Freedman, 2010).

Despite enthusiasm surrounding research on bilingualism as a protective factor, studies have reported conflicting findings. These mixed results highlight methodological challenges in

investigating the potential role of bilingualism as a protective factor in cognitive aging and dementia. After a brief summary of the current research landscape (section 2), this article will discuss multiple methodological issues relevant to the study of bilingualism and late-life cognitive function in order to offer pathways to improve future research: study design, causal inference, and confounding factors (section 3), operationalizing bilingualism (section 4), predicting cognitive level versus age-related cognitive change (section 5), and incorporating brain structural variables (section 6).

2. The current research landscape of AD studies

Research studies that have investigated the relationship between bilingualism and AD can be separated into two categories: (1) cross-sectional, retrospective clinic-based studies and (2) longitudinal, prospective community-based studies. In retrospective clinic-based studies, participants are identified from a specialty clinic, and AD onset is defined by self- or caregiver-report of first dementia symptoms. Cross-sectional analyses test for a relationship between bilingualism and reported age at symptom onset. In prospective community-based studies, participants are identified from the population and followed over time to identify the onset of dementia using standardized cognitive and functional assessments. Longitudinal analyses test for a relationship between bilingualism and objectively-identified age at symptom onset. Table 1 summarizes the results of these two types of studies in the extant literature.

The methodological divide that distinguishes positive and negative results regarding the effect of bilingualism on dementia onset is apparent. Studies that retrospectively identify dementia symptoms among patients in specialty memory clinics usually find significant differences between bilinguals and monolinguals, whereas longitudinal studies that recruit participants from the community and prospectively evaluate dementia incidence based on direct, comprehensive assessment do not. Fuller-Thompson (2015) suggests that this divide may be due to publication bias: less methodologically rigorous retrospective studies are less likely to be published if there are null results, whereas rigorous prospective studies may be more likely to be published regardless of the results.

Other factors that may explain this divide include two of the inherent limitations of retrospective clinic-based studies. First, they are vulnerable to selection bias, as their participants were referred to or sought out by specialty memory clinics and are not representative of the general population (Valian, 2014). Second, age of symptom onset is determined by subjective patient or informant report, which is susceptible to recall bias and may vary systematically across cultural groups. For example, in one U.S. study, ethnic minority caregivers and those with less formal education were more likely to attribute dementia-related symptoms to psychosocial stress or normal aging, rather than dementia (Hinton, Franz, Yeo, & Levkoff, 2005). In some clinic-based studies (e.g., Chertkow et al., 2010), age of dementia diagnosis was defined as age of presentation to the clinic, which can be influenced by factors such as education, socioeconomic status, regional or economically-based patterns of provider referrals, and cultural expectations about cognitive aging (Farias, Mungas, Reed, Harvey, & DeCarli, 2010).

3. Study design, causal inference, and confounding factors

In retrospective studies, cross-sectional associations cannot establish that bilingualism causes superior cognitive skills or outcomes. In the ideal experimental design, people would be randomized to remain monolingual or learn one or more additional languages, and later life cognitive outcomes would be assessed. To our knowledge, no such studies have been conducted. In lieu of randomized experiments, quasi-experiments and longitudinal observational studies offer the best available options for examining the causal influence of bilingualism on late-life cognition. In the current research landscape (see Table 1), prospective studies that assess bilingualism and cognitive status at baseline, characterize potential early and midlife confounders, and determine dementia onset at follow-up using standardized research criteria, are best equipped to investigate causal relationships (Glymour, 2006).

It should also be noted that immigration is not an ideal natural experiment in bilingualism because education, socioeconomic status, and underlying intellectual and cognitive abilities may all affect who immigrates and whether an immigrant becomes bilingual. In several of the clinic-based studies summarized above, the bilingual cohort was primarily immigrant, while the monolingual cohort was predominantly native-born. This introduces potential selection bias and vulnerability to the “healthy immigrant effect.” Prior research that suggests in some countries, despite having lower education, occupational status, and income, immigrants have better general health and lower mortality than non-immigrants (Fuller-Thomson, Nuru-Jeter, Richardson, Raza, & Minkler, 2013). Therefore, the “healthy immigrant effect” may explain relationships between bilingualism and better cognitive outcomes in some studies (Fuller-Thomson & Kuh, 2014; Hill, Angel, & Balistreri, 2012). This suggests that research on all-immigrant cohorts who differ in L2 proficiency may be advantageous (Zahodne, Schofield, Farrell, Stern, & Manly, 2014).

Reverse causation is another threat to conclusions about the role of bilingualism in cognitive aging because initial cognitive function (which also influences age-related cognitive decline) may affect the ability to acquire a second or third language. In other words, better executive control or episodic memory may precede and facilitate the comprehensive acquisition of a second language. However, a recent study in the Lothian Birth Cohort provided evidence against reverse causation by documenting a cross-sectional association between bilingualism and late-life cognitive level independent of IQ at age 11 (Bak, Nissan, Allerhand, & Deary, 2014).

There may be other profound differences in economic, cultural, genetic, or psychosocial variables between bilinguals and monolinguals that confound the relationship between bilingualism and later life cognitive outcomes. If confounders are unmeasured or poorly measured, the association between bilingualism and cognitive function may be over- or under-estimated (Bak, 2016; Paap, Johnson, & Sawi, 2016). For example, the Bialystok et al. (2007) study included 93 bilinguals who spoke 25 different languages and differed with respect to immigration history and age of L2 acquisition. These factors may independently influence motivation, opportunity, and ability to acquire a second language, as well as cognitive performance and risk for dementia. Although occupational status and years of

education were accounted for, sensitive measures of socioeconomic status (e.g., wealth; Allin, Masseria & Mossialos, 2009) and quality of education (Manly, Jacobs, Touradji, Small & Stern, 2002) were not included. Other potential confounding variables include IQ, acculturation, psychosocial variables, personality, and baseline health.

4. Operationalizing bilingualism for research on cognitive aging and dementia

Many of the studies we have reviewed did not describe characteristics of language learning and language use among bilinguals. Determination of the circumstances in which second, third, or fourth languages are acquired, and the settings in which they are used requires measurement of age of acquisition, frequency of use, context of use (family, educational, occupational), and proficiency level, which can be assessed in terms of comprehension, fluency, reading level, and ease of switching (Luk & Bialystok, 2013; Paap, Johnson, & Sawi, 2016; Valian, 2014). This framework acknowledges the potential importance of the patterns of language switching and the social context of language use and communication on brain networks and cognitive function. In addition to subjective self-report measures (e.g., “How well do you speak [second language]?” “How often and in what contexts do you currently use [second language]?”), well-validated tests of naming, fluency, or reading level may be helpful for objectively assessing second language ability. While many studies operationalize bilingualism as a dichotomous variable, we advocate examining the skills and experiences of bilinguals precisely and on a continuum (Kaushanskaya & Prior, 2015). For example, Gollan et al.’s (2011) study of Spanish-English bilinguals in the United States employed bilingual index scores, determined objectively based on performance on a naming task in English and Spanish. When bilingualism is measured continuously, it is possible to explore whether associations between bilingualism and cognitive outcomes are linear, quadratic, or neither (e.g., threshold).

Lifelong bilinguals are generally defined as those who learn two languages simultaneously in early life and have an equal command of both languages. Other bilinguals may learn their second language in adolescence or adulthood, and their knowledge and use of the two languages may be “unbalanced” (i.e., mastery of their first language is significantly better than their second language, or vice versa). Differences in the experiences and uses of languages among bilinguals are relevant to the possible cognitive benefits of bilingualism. For example, bilinguals who switch more frequently between languages are more likely to out-perform monolinguals on task-switching paradigms and executive control tasks, as compared to bilinguals who switch less frequently (Prior & Gollan, 2011; Scaltritti, Peressotti, & Miozzo, 2015). Early acquisition of a second language, paired with balanced use and proficiency of both languages, is associated with better performance on specific executive function tasks among English-Mandarin bilinguals (Yow & Li, 2015). Different levels and experiences of bilingualism may exert different effects on brain structure, function, and cognition.

Another challenge to operationalizing bilingualism in older adults is that neurodegenerative changes may lead to deterioration of first and/or second language abilities. The same

neuropathological changes that reduce cognitive function (both before and after the onset of clinical dementia) may also increase interference between languages among bilinguals or disproportionately affect comprehension or expression of first or second language.

5. Predicting cognitive level versus age-related cognitive change

Conflicting results of prior studies examining bilingualism and dementia highlight the importance of designing studies that can distinguish between cognitive level and cognitive change. Cognitive level reflects the accumulated benefits or detriments of a lifetime of experiences, while cognitive change more precisely reflects age-related cognitive change and the cognitive effects of advancing neuropathology. While most prior studies find a cross-sectional or baseline advantage associated with bilingualism, longitudinal research has failed to find that bilingualism is independently beneficial for maintaining cognitive function over time or protecting from onset of dementia.

Most of the previously summarized studies examine associations between bilingualism and age of first symptom onset or age of dementia diagnosis rather than relationships between bilingualism and rates of change on continuous measures of cognition. Valian's (2014) review cited Kavé, Eyal, Shorek, and Cohen-Mansfield's (2008) study of 814 Israeli Jewish elders as longitudinal evidence for bilingualism as a protective factor in cognitive aging. In this study, three time-points of data were collected, but analyses were all cross-sectional and did not consider rates of cognitive change. The outcome of the Lothian Birth Cohort study (Bak et al., 2014) was based on one time point of cognitive testing when their mean age was about 72.5.

All prior studies that assessed cognitive change failed to find a protective effect of bilingualism on cognitive aging trajectories (Bialystok et al., 2007; Yeung et al., 2014; Zahodne et al., 2014). Bialystok et al.'s (2007) longitudinal study analyzed associations between bilingual status and rates of cognitive change in the four years following dementia diagnosis. They found no group difference in the slopes of global cognitive decline (based on Mini Mental Status Examination scores) between monolingual and bilingual participants. Similarly, Yeung et al. (2014) assessed global cognition using an expanded Mini-Mental State Examination (3MS) at two time points approximately five years apart. They report no association between bilingual status and baseline 3MS scores or change in 3MS scores over time.

Our 2014 study estimated longitudinal associations between bilingualism and rates of cognitive change within composite scores for four cognitive domains assessed in a comprehensive neuropsychological test battery: memory, executive function, language, and speed over an average of 6.4 years (Zahodne et al., 2014). At baseline, bilingualism was associated with better scores on tests of memory and executive function, indicating differences in cognitive level between bilinguals and monolinguals. However, growth models did not reveal an association between bilingual status and rates of change in any cognitive domain. Further, the baseline bilingual advantage did not translate into delayed onset of dementia independent of confounding variables, such as age of immigration and educational attainment.

6. Incorporating brain structural variables

If the goal of future research is to evaluate whether bilingualism promotes cognitive reserve, future studies should include direct measures of neuropathology. The theory of cognitive reserve was originally proposed to account for the disjunction observed when individuals with substantial levels of brain atrophy did not exhibit signs of cognitive impairment (Stern, 2002, 2012). Thus, cognitive reserve refers to an individual's ability to maintain cognitive functioning despite neuropathology. Cognitive reserve has been linked to lifelong accumulation of cognitively-enhancing experiences, including formal education, occupation, and stimulating mental and physical activities (Fratiglioni, Paillard-Borg, & Winblad, 2004; Sachdev & Valenzuela, 2009). Researchers theorize that the neural mechanisms underlying cognitive reserve involve more efficient utilization of brain networks or enhanced ability to recruit alternate brain networks (Stern, 2002). Bilingualism is a cognitively demanding activity that may build cognitive reserve in a manner similar to other stimulating mental activities (Craik et al., 2010). If bilingualism contributes to cognitive reserve, then older bilinguals may display greater brain pathology than monolinguals matched on cognitive performance (Guzman-Velez & Tranel, 2015).

Two recent neuroimaging studies have examined whether bilingualism is a source of cognitive reserve (Luk, Bialystok, Craik, & Grady, 2011; Schweizer, Ware, Fischer, Craik, & Bialystok, 2012). Schweizer et al. (2012) performed computed tomography scans on 40 monolingual and bilingual patients with probable AD who were similar in terms of age, gender, years of education, and level of cognitive performance. The authors found that bilingual patients showed significantly greater atrophy in the medial temporal lobes, in line with the theory of cognitive reserve. Using diffusion tensor imaging, Luk et al. (2011) examined white matter integrity in the brains of 28 monolingual and lifelong bilingual older adults matched for age, gender, and cognitive performance. They found greater anterior to posterior functional connectivity in bilinguals compared to monolinguals, which the authors interpreted as evidence for bilingualism as a source of cognitive reserve. However, Luk et al.'s (2011) finding that bilinguals showed greater brain integrity than monolinguals who performed similarly on cognitive testing conflicts with the theory of cognitive reserve. As explained above, the theory of cognitive reserve predicts that bilinguals would show less brain integrity than monolinguals matched on cognitive performance. Further, Luk et al.'s assertion that greater functional connectivity compensated for gray matter loss and sustained cognitive performance is speculative, given that the study did not actually measure reductions in gray matter volume. It should be noted that both of these studies had small sample sizes and were cross-sectional. Given the limited and conflicting evidence, we do not yet know whether bilingualism can increase cognitive reserve by modulating the behavioral expression of underlying neuropathology. Further study that includes comprehensive imaging variables, particularly in longitudinal cohorts is warranted.

7. Summary and Methodological Recommendations

In the absence of randomized controlled studies or natural experiments, prospective longitudinal studies offer the best available design for examining the independent contribution of bilingualism to cognitive aging or protection against dementia. Because of

their susceptibility to reverse causation, cross-sectional studies cannot provide evidence that bilingualism causes better cognitive skills. In some bilingual populations, it is possible that executive control and memory abilities precede and facilitate acquisition of a second language. Isolating the impact of bilingualism on cognitive aging requires detailed measurement of potential confounders. Because immigration is tightly correlated with bilingualism in many areas, the diverse causes and experiences of immigration, as well as the “healthy immigrant effect” may confound conclusions about a causal link between bilingualism and cognitive aging or risk for dementia. This suggests that studies in which both monolinguals and bilinguals share a common immigration history, socioeconomic status, educational background, and social circumstances are needed. We recommend that future studies of cognitive aging and dementia fully assess the age, context, and setting in which a second language was acquired, employ both subjective and objective measures of proficiency in first and second languages, and consider current degree of engagement in each language. If we harmonize measures of bilingualism and confounders, separate studies can be combined to increase sample size. Future collaborations between research groups that measure age of acquisition, context of migration, frequency and context of language use, and typology of languages in different cohorts may identify possible critical periods and provide evidence for life-course models.

The recent pattern of null results in longitudinal studies does not rule out possible advantageous effects of bilingualism on age-related cognitive outcomes. Some researchers theorize that differences between the syntactic, phonological, and orthographic structures of multiple languages acquired will differentially impact cognitive outcomes (Loizou & Stuart, 2003; Kormi-Nouri et al., 2008). For example, it is possible that Spanish-English bilinguals are less likely to demonstrate specific cognitive benefits due to the structural similarities of the two languages, whereas the effect may be greater among Mandarin-English speakers (Tao, Taft, & Gollan, 2015). Switching between typologically different languages may present a greater executive challenge, which may be more beneficial in maintaining cognitive function with aging or providing reserve against neuropathology. Conversely, managing two structurally similar languages could present the greater executive challenge due to phonological, lexical, and grammatical interference (Valian, 2014). Thus, a protective effect of bilingualism against dementia may be limited to particular types of bilingual speakers with specific experiences, skills, and language use patterns.

Studying a broad range of countries and communities in which bilinguals live may also shed light on the possible cognitive benefits of bilingualism. Bak and Alladi (2016) suggest that promoting bilingualism research beyond North America would stimulate further understanding of possible ties to cognitive function. Areas like the United States, where bilingualism is the exception, are over-represented in current studies. Clarification of the role of bilingualism in promoting maintenance of cognitive function with age may result from studies where degree of bilingualism is the independent variable, and where bilingualism is not as deeply confounded with race, ethnicity, education, and socioeconomic status. Bak (2016) suggests that “deep-rooted bias against bilingualism” and fear of the “other” lead the scientific community to challenge the possibility that bilingualism has a protective effect on cognitive aging. We think it is inappropriate to attribute either positive or null findings to motivations of researchers; rather, we propose that the role of societal bias should be directly

studied in future work. It is possible that protective effects of bilingualism on cognitive change and incident dementia are offset by negative effects of discrimination among bilinguals who are often members of marginalized groups (e.g., ethnic minorities, immigrants).

In summary, methodological rigor is paramount in the quest to elucidate the role of bilingualism in cognitive aging. Future studies should be explicitly designed to address confounds and improve causal inference. Research questions should be refined to take advantage of the unique characteristics of distinct cohorts. While the diverse experiences of different bilingual populations represent a methodological challenge, this diversity also offers the opportunity to understand the complex interactions between culture, cognition, and the brain.

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Summary of the current research landscape

Table 1.

	Study type	Participants	Operationalization of bilingualism	Operationalization of dementia onset	Covariates	Findings
Alladi et al., 2013	Retrospective, clinic-based, cross-sectional	648 dementia patients from a memory clinic in Hyderabad, India	Family-report of ability to complete everyday communication in two or more languages	Family-report of symptom onset	Formal education, literacy, occupation, rural/urban dwelling, gender, vascular risk factors, family history of dementia, dementia severity	Bilinguals (57% were multilingual) showed symptoms 4.5 years later than monolinguals
Bialystok, Craik, & Freedman, 2007	Retrospective, clinic-based, cross-sectional	184 dementia patients from a memory clinic in Toronto, Canada	Panel of 11 judges determined if patient "spent majority of their lives regularly using two languages"	Caregiver-report of symptom onset	Formal education, occupation, gender, time between symptom onset and first clinic visit, cognitive performance at first visit	Bilinguals showed symptoms 4.1 years later than monolinguals
Craik et al., 2010	Retrospective, clinic-based, cross-sectional	211 AD patients from a memory clinic in Toronto, Canada	Whether patients "spent majority of their lives regularly using two languages"	Patient or care-giver-report of symptom onset	Formal education, occupation, immigrant status, gender, time between symptom onset and first clinic visit, cognitive performance at first visit	Bilinguals showed symptoms 5.1 years later than monolinguals
Chertkow et al., 2010	Retrospective, clinic-based, cross-sectional	632 AD patients from a memory clinic in Montreal, Canada	Patient or caregiver-report of whether patients "spent majority of their lives regularly using two languages"	Family-report of symptom onset	Formal education, occupation, gender, estimated immigrant status, time between symptom onset and first clinic visit, number of languages spoken	No difference between monolinguals and bilinguals Protective delay in symptom onset for multilinguals compared to mono-linguals
Gollan, Salmon, Montoya, & Galasko, 2011	Retrospective, clinic-based, cross-sectional	44 Latino AD patients from a memory clinic in San Diego, USA	Bilingual index scores based on Boston Naming Test performance in both languages	Family-report of symptom onset and age of dementia diagnosis obtained from medical records	Education level, language proficiency and use, cognitive performance at diagnosis	Delayed dementia diagnosis associated with bilingualism for lower educated (11 years) group but not for those with more years of schooling
Crane et al., 2009	Prospective, community-based, longitudinal	2,299 Japanese-American men in Oahu, USA	Self-report of midlife use of written Japanese	Neuropsychological testing and clinical exam	Formal education, income, medical risk	No protective effect of

Study type	Participants	Operationalization of bilingualism	Operationalization of dementia onset	Covariates	Findings
Lawton, Gasquoine, & Weimer, 2015	Prospective, community-based, longitudinal	1,789 Latino participants in Sacramento, USA	Self-report	factors, family history of AD	bilingualism on dementia onset
Sanders, Hall, Katz, & Lipton, 2012	Prospective, community-based, longitudinal	1,779 participants in New York City, USA	Self-report	Formal education, gender, immigrant status, baseline cognitive performance, diabetes status	No protective effect of bilingualism on dementia onset
Yeung, Si, John, Menec, & Tyas, 2014	Prospective, community-based, longitudinal	1616 participants in Manitoba, Canada	Self-report	Formal education, gender, race, immigrant status, marital status, cardiovascular risk factors, literacy	No protective effect of bilingualism on dementia onset
Zahodne, Schofield, Farrell, Stern, & Manly, 2014	Prospective, community-based, longitudinal	1067 Latino participants in New York City, USA	Self-report and scores from the Wide Range Achievement Test-3	Formal education, gender, subjective memory loss, literacy	No protective effect of bilingualism on dementia onset
				Formal education, gender, country of origin, time spent in the US.	No protective effect of bilingualism on dementia onset