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Effects of Bilingualism on the Age of Onset and Progression of MCI and AD: Evidence From Executive Function Tests

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Previous articles have reported that bilingualism is associated with a substantial delay in the onset of both Alzheimer's disease (AD) and Mild Cognitive Impairment (MCI). The present study reports results from 74 MCI patients and 75 AD patients; approximately half of the patients in each group were bilingual. All patients were interviewed to obtain details of their language use, onset of their condition, and lifestyle habits. Patients performed three executive function (EF) tests from the D-KEFS battery (Trails, Color-Word Interference, Verbal Fluency) on 3 occasions over a period of approximately 1 year. Results replicated the finding that bilingual patients are several years older than comparable monolinguals at both age of symptom onset and date of first clinic visit. This result could not be attributed to language group differences in such lifestyle variables as diet, smoking, alcohol consumption, physical activity, or social activity. On the first testing occasion, performance on the EF tasks was generally comparable between the language groups, contesting arguments that bilinguals wait longer before attending the clinic. Finally, EF performance tended to decline over the 3 sessions, but no differences were found between monolinguals and bilinguals in the rate of decline.

Keywords: bilingualism, Alzheimer's disease, mild cognitive impairment, cognitive reserve, executive control

A growing body of research has demonstrated that bilingualism leads to enhanced performance on a range of executive function tasks that assess various attentional control processes (reviews in Bialystok, Craik, Green, & Gollan, 2009; Hilchey & Klein, 2011). These bilingual advantages have been reported across the life span, including infants (Brito & Barr, 2012; Kovács & Mehler, 2009), toddlers (Poulin-Dubois, Blaye, Coutya, & Bialystok, 2011), children (Adi-Japha, Berberich-Artzi, & Libnawi, 2010; Bialystok, 2011; Carlson & Meltzoff, 2008), young adults (Costa, Hernández, & Sebastián-Gallés, 2008; Prior & MacWhinney, 2010), and older adults (Bialystok, Craik, Klein, & Viswanathan, 2004; Salvatierra & Rosselli, 2010). The explanation for this bilingual superiority has been traced to the generalization of executive function processes, such as inhibition (e.g., Green, 1998), monitoring (e.g., Costa, Hernandez, Costa-Faidella, & Sebastian-Galles, 2009), and coordination (e.g., Bialystok, 2011), that are needed to control attention to jointly activated languages. Consistent with this view, Blumenfeld and Marian (2011) reported that bilingual participants showed a correlation between performance on a nonverbal Stroop task and a verbal word selection task, both of which require the inhibition of distracting alternatives, but there was no correlation between these tasks for monolinguals. Supporting fMRI evidence is presented in a meta-analysis of 10 studies showing that simple language switching by bilinguals is carried out by the same executive function network used in nonverbal conflict tasks (Luk, Green, Abutalebi, & Grady, 2012). Recently, a study by Gold, Kim, Johnson, Kryscio, and Smith, 2013 confirmed a bilingual

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advantage in task-switching for younger and older adults, and found that better performance was associated with more efficient neural processing as measured by fMRI activation levels. Finally, neuroimaging evidence from monolingual and bilingual participants performing executive functioning tasks indicates different patterns of neural recruitment in the two language groups during task performance (Abutalebi et al., 2012; Bialystok et al., 2005; Garbin et al., 2010; Luk, Anderson, Craik, Grady, & Bialystok, 2010). Together, this research points to a substantial impact of bilingualism that both increases the ability to perform an important set of cognitive tasks and reorganizes neural networks recruited for that performance.

The participants in these studies were all healthy individuals who were either typically developing children or adults experiencing normal cognitive aging. However, executive functioning declines with healthy aging (Craik & Bialystok, 2006) and is particularly vulnerable when aging includes cognitive impairment or dementia. Deficits in executive functions have been identified as markers for the progression of Alzheimer's disease (AD) along with the more commonly cited memory impairments (Albert, Moss, Tanzi, & Jones, 2001; Bäckman, Jones, Berger, Laukka, & Small, 2005; Clark et al., 2012) and are also involved in mild cognitive impairment (MCI; Albert et al., 2011; Albert, Blacker, Moss, Tanzi, & McArdle, 2007; Crowell, Luis, Vanderploeg, Schinka, & Mullan, 2002; Lafleche & Albert, 1995). Moreover, deficits in specific executive functions are predictive of further cognitive decline, for example, inhibition and switching in AD (Bondi et al., 2002; Clark et al., 2012), and planning, problem solving, and working memory in MCI (Brandt et al., 2009).

Contributing at least in part to these executive function disturbances is atrophy of various frontal brain regions known to accompany normal aging (Raz, Ghisletta, Rodrigue, Kennedy, & Lindenberger, 2010; Resnick, Pham, Kraut, Zonderman, & Davatzikos, 2003) that is greatly exacerbated in MCI (McDonald et al., 2012) and AD (Laakso et al., 1995; McDonald et al., 2009; Sabuncu et al., 2011). The frontal lobes have long been thought to be responsible for executive functions (Miller & Cohen, 2001; Stuss & Alexander, 2000), and importantly, frontal atrophy has been related to cognitive decline and executive function impairments in older adults with cognitive difficulties (Laakso et al., 1995; McDonald et al., 2012). If bilingualism is associated with an enhancement of frontal lobe functions, then bilingual patients may be better able to cope with the consequences of such diseases than their monolingual counterparts. Several studies have provided preliminary evidence for this possibility and have shown that bilingual patients are diagnosed with AD about 4–5 years later on average than monolingual patients, who are otherwise comparable on a range of measures (Bialystok, Craik, & Freedman, 2007; Craik, Bialystok, & Freedman, 2010). However, further studies have shown that a number of other variables, such as level of education (Gollan, Salmon, Montoya, & Galasko, 2011), knowledge of multiple languages (Chertkow et al., 2010), and socioeconomic background (Chertkow et al., 2010; Gollan et al., 2011) interact with bilingualism and also play a role in deferring the onset of symptoms.

Some studies have failed to find protective effects of bilingualism. A study by Crane et al. (2010) examined cognitive ability in a large sample of nondemented Japanese American older men and found no relation between their self-reported use of spoken and written Japanese and rate of cognitive decline over 10 years. However, the study relied on self-assessment of Japanese and no information was available on other languages spoken by the participants. In a second example, Sanders, Hall, Katz, and Lipton (2012) conducted a longitudinal study and concluded that bilingual activity is actually disadvantageous in cognitive aging. However, their measure of bilingualism was indirect; they contrasted individuals whose native language was English with those with a different first language. Using this definition, their results showed that bilinguals diagnosed with dementia were significantly older than comparable monolinguals at time of diagnosis—a finding consistent with our own results—but based their conclusions from the study on an analysis of incident risk. To this end, they reported that for individuals with low and intermediate educational attainment, non-native English speakers ("bilinguals") had fewer cases of incident dementia than native English speakers, but that there was a greater risk of dementia for non-native English speakers in the high education stratum. The explanation for this possible interaction between language history and educational attainment is not at all obvious. In general, claims for the delayed onset of symptoms of dementia in bilinguals still require corroborating evidence.

Our interpretation of the protective effect of bilingualism against symptoms of dementia is that the lifelong use of two or more languages contributes to cognitive reserve, the notion that stimulating activities serve to maintain brain and cognitive function (Stern, 2002, 2009). This conclusion, however, depends on evidence that the monolingual and bilingual patients seek medical advice at comparable levels of cognitive impairment and that bilinguals did not simply delay seeking treatment, thus appearing older at diagnosis. In the studies by Bialystok, Craik, and Freedman (2007) and Craik, Bialystok, and Freedman (2010), patients in the two language groups performed equivalently on broad cognitive assessments such as the Mini-Mental State Exam (MMSE; Folstein, Folstein, & Fanjiang, 2001), a measure of global cognitive level. More compelling evidence comes from a study by Schweizer, Ware, Fischer, Craik, and Bialystok (2012) examining 20 monolingual and 20 bilingual patients who had been diagnosed with probable AD. The average age of patients was 77 years in both groups, and the groups were matched for cognitive level as measured by the Behavioral Neurology Assessment (BNA) test of cognitive function (Darvesh, Leach, Black, Kaplan, & Freedman, 2005). Additionally, monolinguals and bilinguals did not differ on further neuropsychological tests including MMSE and Clock Drawing (Shulman, Gold, Cohen, & Zucchero, 1993). Computed Tomography (CT) scans were obtained for all patients to determine the extent of brain atrophy. Measurements associated with normal aging were comparable for the two groups. In contrast, the neural measurements considered to index AD severity, specifically the temporal horn ratio, third ventricle ratio and suprasellar cistern ratio in the medial temporal lobe (Zhang et al., 2008), showed significantly *more* atrophy in the bilingual group, indicating more disease pathology. These results confirm that bilingual patients who were functioning at a cognitive level equivalent to monolingual patients were coping with more disease burden in the form of atrophy and, therefore, presumably more advanced disease. That is, the protection afforded by bilingualism apparently enabled these patients to function at a higher level than their degree of brain atrophy would predict.

If bilingualism continues to protect patients with dementia by enabling them to cope with the disease and function for a longer time in spite of its progression, it may be that this later onset of symptoms is associated with a more rapid decline in functioning subsequent to symptom onset. Such an outcome would reduce and eventually eliminate the initial advantage. The evidence on this point is mixed. Valenzuela and Sachdev (2006) reported results in favor of the notion that higher levels of brain reserve continue to slow the rate of cognitive decline in older people, but the bulk of the evidence shows that reserve factors such as higher levels of education delay the onset of symptoms but are then followed by a faster rate of decline following diagnosis (Hall et al., 2007, 2009; Scarmeas, Albert, Manly, & Stern, 2006).

To explore these questions more fully, the present study investigated both monolingual and bilingual patients diagnosed with AD or with MCI. In a recent study, our group reported a delay in symptom onset and diagnosis for bilingual patients with single-domain amnestic MCI, although there was no language group difference in onset of multiple-domain amnestic MCI (Ossher, Bialystok, Craik, Murphy, & Troyer, 2013). However, no research to date has examined the progression of the disease over time in MCI patients.

The present study addressed three main questions. First, we asked whether the protection against onset of symptoms found for bilinguals in AD and MCI remained when a wide range of background and lifestyle factors is considered. Patients in the two language groups in previous research were not carefully matched on potentially relevant background factors. For example, in both the study by Bialystok et al. (2007) and Craik et al. (2010), the monolingual patients had significantly more formal education than bilinguals, a difference that should provide protection to monolinguals. Nonetheless, it was the bilingual patients in both studies who showed symptoms of disease later than monolinguals. Therefore, we included a lifestyle questionnaire to obtain information about such issues as diet, exercise, and alcohol consumption to determine whether factors besides bilingualism might be associated with delayed onset and diagnosis.

Second, previous research has typically used broad indicators of cognitive functioning (e.g., MMSE) to equate monolingual and bilingual patients on cognitive level, but bilingual advantages are generally found in measures of executive functioning. Tasks designed to assess executive functioning offer more sensitive and specific measures of cognitive performance than do broad measures such as MMSE. No research to date has provided detailed comparisons of monolingual and bilingual AD or MCI patients on executive functioning. Minimally, it is necessary to demonstrate that older bilingual patients have maintained executive function levels at least as well as their monolingual counterparts. This is essential to support the argument that the bilingual patients are older because their ability has remained intact and not because they have delayed treatment. Therefore, we administered a standardized battery of executive functioning tasks to all patients.

Third, to determine whether differences in age of onset of MCI and AD are associated with different rates of decline subsequent to the appearance of symptoms, patients were followed at approximately 6-month intervals for up to about 1 year and the executive function tasks were readministered in each session to identify changes in cognitive level. These results will provide a more broadly based evaluation of the role of bilingualism in coping with dementia than is currently available.

Documenting answers to these three questions will enable us to address methodological limitations of previous research, understand in more detail the role of bilingualism in aging that involves cognitive impairment and dementia, and provide preliminary evidence regarding the trajectory of bilingual and monolingual patients after diagnosis.

Method

Participants

One-hundred and 49 patients were recruited from the Sam and Ida Ross Memory Clinic at Baycrest, Toronto, Canada. All patients included in the study had received a consensus diagnosis of probable AD (McKhann et al., 1984) or MCI (Albert et al., 2011) by a team comprised of at least two physicians (neurologist, geriatrician, or psychiatrist) and a neuropsychologist. Participants were identified from their chart information following the initial clinic appointment based on complaints about their memory or cognitive function. Exclusion criteria for participation included a primary diagnosis of depression, seizures, head injury, normal pressure hydrocephalus, cancer, medication-related cognitive impairment, alcoholism, bipolar disorder, schizophrenia, learning disability, or any other psychiatric or neurological condition aside from incipient dementia.

Participants were assigned to the monolingual or bilingual group based on information from the Language and Social Background Questionnaire (LSBQ; see below for more detail). The criterion for bilingualism was that individuals had spent the majority of their lives, beginning at least in early adulthood, speaking two or more languages fluently—ideally daily, but at least weekly. We required that extensive use of both languages had continued until the time of testing, except in circumstances where cognitive impairment or dementia was the suspected cause of disturbances in regular language use. All patients were proficient in English, but bilinguals additionally spoke a variety of other languages (e.g., Farsi, French, Italian, Russian, Yiddish) and did not represent any single specific sociocultural group. Some participants spoke more than two languages but were included in the bilingual group.

The sample consisted of 74 individuals diagnosed with MCI (38 monolingual and 36 bilingual) and 75 individuals diagnosed with probable AD (35 monolingual and 40 bilingual). Of the 75 AD patients, 35 had been seen in our clinic prior to April 2009 and were included in a previous study reporting only age of symptom onset and age of diagnosis in a total sample of 211 AD patients (Craik et al., 2010). No cognitive test scores or progression scores have been previously reported for these patients. The results for the MCI patients, including their age of onset of symptoms and test score data are reported here for the first time. Details for all patients are given in Table 1.

Tasks and Instruments

Language and Social Background Questionnaire (LSBQ). All testing was carried out with the participant in the presence of a caregiver or relative who was involved in completing the questionnaires. The LSBQ elicited information about each participant's

Table 1
Participant Data and Background Measures (With Standard Deviations) by Group

	MCI		AD	
	Monolingual	Bilingual	Monolingual	Bilingual
N	38	36	35	40
Sex (F:M)	19:19	20:16	19:16	22:18
Immigrant (Y:N)	12:26	25:11	8:27	27:12[1]
Onset age	62.2 (13.2)	66.9 (11.1)	70.9 (11.0)	78.2 (8.9)
Clinic age	66.5 (12.3)	70.0 (10.7)	74.2 (11.2)	81.4 (8.4)
Years education	15.5 (3.8)	14.3 (3.9)	12.5 (3.7)	12.2 (4.9)
BNA	95.4 (11.1)	90.6 (12.5)	72.7 (16.8)	63.8 (14.6)
MMSE	29.0 (1.4)	28.4 (1.9)	23.4 (3.8)	22.3 (4.5)

[1] One patient did not supply immigration history.

birth, immigration history, education, and language use. Participants who reported speaking more than one language were asked to state the age at which they began to speak their second language fluently, specify how often they used each language (daily, weekly, monthly, occasionally), and rate their competence in each language (poor to fluent). Participants reporting more than two languages were asked to provide this information for each additional language. Participants were classified as bilingual if they had learned their second language no later than early adulthood and reported proficient use of both languages on at least a weekly basis since that time, with the caveat described above regarding cognitive decline preventing regular use.

Lifestyle questionnaire. Participants were asked to answer questions about their diet and other activities on a 4-point scale (scored 3, 2, 1, 0) where higher numbers always indicated more positive or healthy choices. Diet items included the current frequency of consuming vegetables, fruit and fish; each of the three scales ran from *daily* to *never* (3–0). Additionally, participants were asked to what extent this pattern reflected diet throughout their entire lives, and a 5-point change score was allocated to reflect the degree of change from previous to present habits. The change scale ran from *much better now* (−4) through *somewhat better now* (−2) to *no change* (0), *somewhat worse now* (+2), and *much worse now* (+4). The current assessment score modified by the change score thus provided a final score that characterized their adult life before disease onset rather than their present situation. A composite score for diet was obtained by summing the three scores for vegetables, fruit, and fish (maximum of 9 points), and then adding the change score to the total. For example, if a participant checked 3 for vegetables, 3 for fruit, 2 for fish, and stated that this pattern was somewhat better than formerly, the life span composite score would be (3 + 3 + 2 − 2) = 6. In a further effort to regulate the scores, the composite scores for diet were constrained to fall between 0 and 9. More extreme scores are possible (+13 to −4) but only three individuals scored outside the 0–9 range, and they were within two points of 0 or 9. These scores are shown on the first line of Table 2.

The questionnaire also gathered information about frequency of alcohol consumption, smoking, physical activity, and social activity. In each case the initial answer was on a 4-point scale (3, 2, 1, 0) where 3 was the healthiest choice. Again a 5-point change score (−2, −1, 0, +1, +2) was added to the initial answer to provide the final life span scores shown in Table 2. In this case life span scores were constrained to fall between 0 and 3.

Onset of symptoms interview. Research indicating a delay in onset of symptoms (Bialystok et al., 2007; Craik et al., 2010) necessarily relies on subjective reports from patients or caregivers. To obtain more detailed information, we included a questionnaire to establish when patients or their families first noticed there was cognitive impairment. Participants (and their family members) were asked when they first noticed changes in memory or other cognitive abilities, and what kinds of things they noticed. They were also asked when friends or family had noticed the changes. We then probed more specifically whether they had experienced changes in their ability to remember things, the types of things they had difficulty with, and when they had first noticed these experiences. These questions were repeated focusing on changes in the ability to concentrate, speak, and communicate, and on aspects of cognitive ability not covered by the other questions. All responses were corroborated by a family member or caregiver wherever possible, usually a spouse or child who was living with the patient or performing caregiving duties.

Delis-Kaplan Executive Function System Tests. Three tests from the Delis-Kaplan Executive Function System (D-KEFS; Delis, Kaplan, & Kramer, 2001) battery were administered as measures of executive function. The D-KEFS tests are designed for use with a wide range of ability including normal individuals and those with brain damage. The tests assess a number of executive functions, providing a profile of executive functioning rather than a single score. Because frontal brain regions that support executive functions are known to be affected by AD, older adults who were more impaired as a result of their disease should show greater deficits, especially on the most challenging subtests of the battery. The D-KEFS battery was also chosen because it provides comparison scores that allow the separation of low level abilities from higher level cognitive functions and the assessment of subtle deficits at higher levels of task difficulty.

The first test was the Trail Making Test (TMT) to assess flexible thinking in the visuomotor domain and included the number sequencing (Trails A) and number–letter switching (Trails B) conditions. Standard test termination procedures were followed.

The second test was the Color-Word Interference Test (CWIT), which measures the ability to inhibit an automatic or highly-learned response. The subtests were color naming, inhibition, and inhibition-switching, administered in that order. A Stroop effect

Table 2
Mean Responses (and SD*s) to Lifestyle Questionnaire Measures*

Measure	MCI		AD	
	Monolingual *M* (*SD*)	Bilingual *M* (*SD*)	Monolingual *M* (*SD*)	Bilingual *M* (*SD*)
Diet[1]	5.39 (1.90)	5.49 (2.33)	5.60 (2.61)	5.90 (2.23)
Alcohol	1.53 (.95)	1.83 (.89)	1.91 (1.12)	2.28 (.91)
Smoking	2.00 (1.07)	1.54 (1.09)	1.77 (1.17)	1.95 (.99)
Physical activity	2.24 (.75)	2.00 (.97)	1.80 (.90)	1.90 (.87)
Social activity	2.34 (.63)	2.26 (.78)	2.34 (.76)	2.33 (.84)

Note. Higher scores = healthier options.
[1] Means for Diet are out of a possible 9, and means for the other variables are out of a possible 3 (see text).

score was calculated from the scores obtained for naming the ink color in the standard color naming condition and naming the ink color in the inhibition condition where the color word interfered. In the inhibition-switching condition, the words were the same as in the inhibition condition but some were enclosed in rectangles. Participants were instructed to name the ink color if there was no rectangle but read the word if it was inside a rectangle. This requires participants to switch between two rules within the same task and can reveal deficits in cognitive flexibility even if the participant has relatively intact verbal inhibition.

The third task included three subtests of the Verbal Fluency Test (VFT): letter fluency, category fluency, and category switching. Letter fluency tested the ability to produce words based on initial phonemes with an effortful set of phonemic restrictions that excluded proper nouns, numbers, and variations on the same words. Category fluency assessed access to conceptual categories, and category switching required alternating between two categories.

For all D-KEFS tasks, raw scores were converted to age-normed standardized scores. The scoring system is based on a mean population score of 10 and standard deviation of 3. In all cases higher scores reflect better cognitive performance. The scoring system allows for the calculation of comparison scores up to the age of 89 years; therefore, for the few participants over the age of 89, we used the norms from the highest available age range.

Procedure

Participants indicating an interest in research were contacted and informed about the nature of the study, the time commitment, and the types of tasks that would be administered. If they and their family member or caregiver provided substitute decision maker consent, a trained research assistant visited the participant at home to administer the informed consent document and test battery. All tests and questionnaires were administered in a single testing session lasting approximately 1 1/2 hours. The first session was completed within several months of the patient's first clinic visit, and subsequent sessions followed at intervals of 6–7 months, depending on the patient's availability. The study was approved by the Baycrest Research Ethics Board.

Scores from the MMSE and BNA were obtained from the initial visit to the memory clinic. In the first home testing session, the tests were administered in the order LSBQ, Lifestyle Questionnaire, Onset of Symptoms Interview, and D-KEFS tests (TMT, CWIT, VFT). On subsequent visits only the D-KEFS tests were administered. Participants received compensation for their time.

Results

Background and Age of Onset

The background measures for the participants are summarized in Table 1. In this sample, 73% of monolingual patients and 31% of bilingual patients were born in Canada. Immigrants had fewer years of formal education than nonimmigrants ($F(1, 143) = 6.05$, $p = .02$) and patients with AD had fewer years of education than patients with MCI ($F(1, 144) = 13.71$, $p = .0003$).

Table 1 shows that bilingual patients reported later onset ages than monolinguals for both the MCI group (by 4.7 years) and the AD group (by 7.3 years). Comparable figures for the differences in age of their first clinic visit in the bilingual group are 3.5 years for the MCI group and 7.2 years for the AD group. To assess these effects, a 2-way ANOVA for language group and diagnosis was conducted for each age measure. There were main effects of both factors: AD patients were older than MCI patients for both onset of symptoms ($F(1, 145) = 30.45$, $p < .0001$) and age of first clinic visit ($F(1, 146) = 29.70$, $p < .0001$); also, bilinguals were older than monolinguals for both onset of symptoms ($F(1, 145) = 10.75$, $p = .001$) and age of first clinic visit ($F(1, 146) = 9.35$, $p = .003$). No interaction was found between language group and diagnosis for either onset of symptoms, $F < 1$, or age of first clinic appointment, $F < 1$. Including education and immigration in the model did not alter the findings. Importantly, in spite of a substantial difference in immigration history between monolinguals and bilinguals, the partial correlation between immigration status and onset age is essentially zero, $r = -0.02$.

As expected, patients with AD had lower MMSE scores ($F(1, 142) = 102.85$, $p < .0001$) and lower BNA scores ($F(1, 137) = 116.64$, $p < .0001$) than patients with MCI. There was a borderline effect of language group showing lower scores for bilinguals for MMSE ($F(1, 142) = 3.87$, $p = .05$) and BNA when immigration was held constant ($F(1, 137) = 3.29$, $p = .07$). Note, however, that bilinguals were significantly older than monolinguals and these scores are not standardized for age. Both MMSE ($F(1, 142) = 5.09$, $p = .03$) and BNA ($F(1, 136) = 8.75$, $p = .004$) were associated with more years of education. These results confirm the previous reports showing later onset of symptoms and diagnosis in bilinguals for both AD (Bialystok et al., 2007; Craik et al., 2010) and MCI (Ossher et al., 2013).

Lifestyle Questionnaire scores are summarized in Table 2. The reason for collecting these data was to ascertain whether the observed difference in age of onset between the language groups was attributable to some difference in lifestyle rather than to language experience. There were two steps in the examination of the contribution of the lifestyle (diet, alcohol, smoking, physical activity, and social activity) and demographic measures (immigration and education) to the ages reported for symptom onset and first clinic visit. First, differences on these measures between monolingual and bilingual patients were quantified using Cohen's *d* statistic and were examined concurrently with partial correlation coefficients between each measure and onset age controlling for language group; and second, each measure was used as a covariate to see whether its inclusion in the analysis of variance model substantively altered the finding regarding language group.

The Cohen's *d* statistic for each measure is represented in Figure 1 by red columns. The scale on the left axis shows the difference between language groups, with larger positive values indicating healthier outcomes for bilingual patients and larger negative values indicating healthier outcomes for monolingual patients. The lifestyle and demographic variables are presented in descending order of observed Cohen's *d*. For patients in the AD group, there was a small–medium difference between language groups favoring the bilingual group for alcohol consumption and a small difference for smoking, that is, bilingual patients reported less alcohol consumption and smoking than did monolingual patients. For MCI, there was a small difference between language groups showing that bilingual MCI patients also reported less alcohol consumption than did monolinguals. However, monolingual patients with MCI reported slightly healthier lifestyle habits for smoking and physical

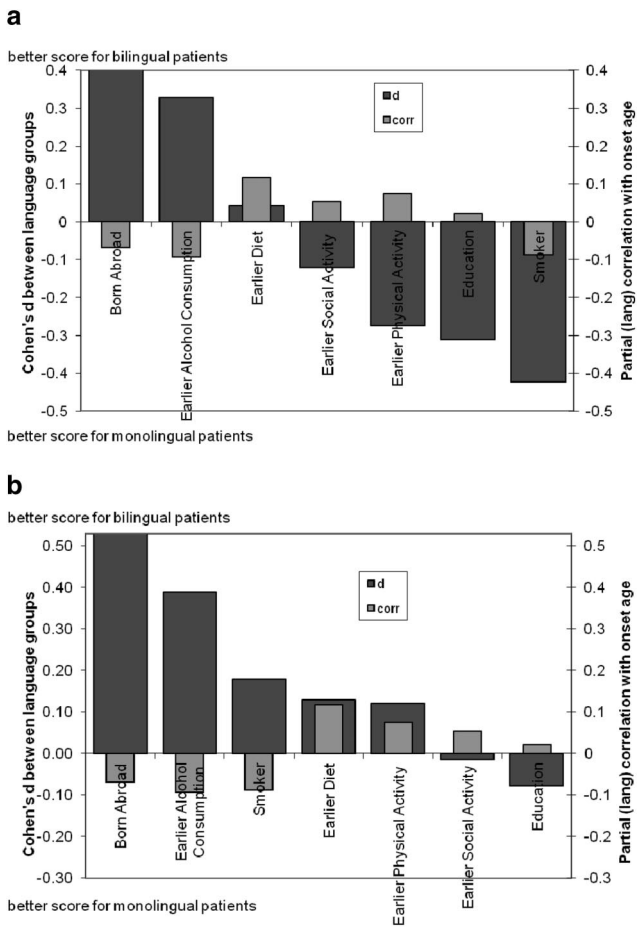

Figure 1. Demographic and lifestyle factors—differences between language groups and associations with onset age for (a) MCI and (b) AD patients. Red bars give values of Cohen's *d* for differences between monolingual and bilingual groups. Blue bars indicate partial correlations between each variable and onset age, conditional on language group (see text).

activity measures than did bilingual MCI patients. The relatively large value of Cohen's *d* for "born abroad" simply reflects the fact that more bilinguals than monolinguals were immigrants.

To determine the extent to which these small differences in lifestyle habits were associated with age of onset of MCI and AD, we calculated partial correlation coefficients between each lifestyle variable and onset age, conditional on language group. These partial correlation coefficients are plotted in blue in Figure 1 on the right axis such that positive correlations indicate that healthier scores are associated with older age at onset. Thus, if the group with the better lifestyle measure given by Cohen's *d* also showed a larger correlation between that lifestyle variable and the partial correlation, the two bars would have the same sign, raising concern that part or all of the bilingualism effect is attributable to that lifestyle variable rather than to bilingualism per se. For example, if bilinguals smoked less, and less smoking is associated with later onset, is the delay in symptoms due to bilingualism or to smoking? However, the only measures for which Cohen's *d* and the corresponding partial correlation were in the same direction were diet and physical activity (positive) for AD and smoking (negative) for MCI. When the lifestyle measures that showed Cohen's *d* and partial correlation with the same direction were included in the model for onset age in the AD group (diet or physical activity), the language effect was reduced very slightly but was still significant. In contrast, in cases where Cohen's *d* and the partial correlation are in opposite directions, as in alcohol consumption, smoking, and social activity, the relation between language group and age of onset of dementia was slightly amplified by including these measures in the model. In the MCI group, the reported association between language group and onset age was not modified substantively by inclusion of any lifestyle measure in the model. These results, therefore, show minimal effects of these lifestyle variables on the age of onset of symptoms and age of first clinic appointment for both MCI and AD patients in the present sample.

Executive Function Tasks in First Session

The mean scores and standard deviations for the D-KEFS tasks are reported in Table 3, which also shows effect sizes (Cohen's *d*) for comparisons between the language groups. The primary analysis was a 2-way ANOVA including language group and diagnosis as main effects, and their interaction. These analyses were conducted separately on each of the component subtests because the components varied in difficulty and in the precise cognitive process that was targeted. A nonsignificant interaction term was removed prior to interpretation of main effects. Immigration status and education were subsequently added to the model to evaluate the potential role of these factors in the outcomes.

Some patients did not complete one or more of the more complex component subtests of the D-KEFS tests. Therefore, we used logistic regression to model the association between completion of the more complex subtest and performance on the simplest subtest. The fitted model and observed covariates were used to estimate the probability that the more complex subtest was completed. The reciprocal expected probability was used to weight participants with complete data in a rerun of the ANOVA on the observed outcome values for the more complex subtest. For example, if only half of the participants with a given score (e.g., 6 on the simpler subtest) completed the more complex subtest, the scores of the "completers" on the complex test were double weighted to compensate for the missing participants who performed equivalently on the simpler subtest. Although this analysis accommodates missing observations on the more complex subtest, it assumes that the dropouts would have performed similarly to the completers on the subtest with the missing value. This is clearly a strong assumption; it is likely that a participant who did not complete the more complex version possessed less ability than a participant who did even if their scores on the simpler subtest were equal. The distribution of weights was examined in order to screen for overly influential weighting of individual patients (Hogan, Roy, & Korkontzelou, 2004).

Trail making test (TMT). For number sequencing, the ANOVA showed a main effect of diagnosis, with MCI patients obtaining higher scores than AD patients ($F(1, 143) = 68.81$, $p < .0001$), but no effect of language group, and no interaction between language and diagnosis. In the number–letter switching condition, there was an interaction between language group and diagnosis ($F(1, 120) = 4.33$, $p < .04$) in which completion times were

Table 3
Means and Standard Deviations of Standardized Scores (Population Mean of 10.0 and SD *of 3.0) on D-KEFS Tests*

	MCI					AD				
	Monolingual		Bilingual			Monolingual		Bilingual		
Task measure	N	*M* (*SD*)	N	*M* (*SD*)	*d*	N	*M* (*SD*)	N	*M* (*SD*)	*d*
Trails										
Number sequencing	38	9.68 (3.53)	36	9.03 (4.53)	0.16	33	3.91 (3.77)	39	4.08 (3.71)	−0.05
Number–letter switching	37	**10.24** (2.69)	35	**8.34** (3.63)	0.60	25	4.68 (4.05)	27	5.37 (3.40)	−0.19
Color–word interference										
Color naming	38	9.26 (2.97)	34	8.74 (3.03)	0.17	29	5.41 (4.02)	35	4.80 (4.04)	0.15
Inhibition	37	9.30 (3.26)	33	9.21 (3.30)	0.03	25	5.84 (4.67)	31	6.42 (4.14)	−0.13
Stroop effect	37	9.95 (2.58)	32	10.38 (2.47)	−0.17	25	**9.88** (3.32)	29	**11.55** (3.69)	−0.47
Inhibition switching	36	8.86 (3.44)	33	8.55 (3.14)	0.09	17	4.82 (4.23)	29	5.03 (4.13)	−0.05
Verbal fluency										
Letter fluency	38	11.45 (3.62)	36	10.61 (3.84)	0.23	34	7.47 (4.35)	35	5.94 (3.91)	0.37
Category fluency	38	8.95 (3.00)	36	7.94 (2.99)	0.34	34	5.47 (3.04)	35	4.74 (3.41)	0.23
Category switching	38	9.32 (3.33)	36	8.78 (2.58)	0.18	34	4.79 (3.47)	35	4.89 (3.01)	−0.03

Note. Effect sizes (*d*) for differences between the language groups are also shown. significant differences ($p < .05$) between language groups are shown in bold print.

significantly slower for bilingual than monolingual patients with MCI, but the analysis found no language group difference in patients with AD. Inclusion of any one of the five lifestyle measures (diet, alcohol, smoking, physical activity, and social activity) in the model did not substantively alter the findings. In general, we only report data showing whether the lifestyle measures modulated the effects of language group and diagnosis on the executive function scores; we do not report any direct effects of the lifestyle measures on the executive function scores themselves.

Of the 72 patients with AD who performed the number sequencing subtask, 52 (72%) performed the more complex number–letter switching section. Patients with MCI tended to complete all subtests if they performed the simple version (number sequencing $n = 74$; number–letter switching $n = 72$). The logistic regression model did not uncover an association between the probability of performing number–letter switching and bilingualism or any interaction with diagnosis or performance on number sequencing ($p > .40$). An interaction was found, however, between performance on simple number sequencing and diagnosis ($\chi^2 = 3.89$, $p = .05$). Specifically, for AD patients, the probability of performing the number–letter switching subtest was associated with performance on the simple number sequencing subtest ($\chi^2 = 7.21$, $p = .007$), but no relation was found between the two subtests for MCI patients ($\chi^2 = 0.09$, $p = .76$), presumably because of ceiling effects. These data are shown in Figure 2. The probability of completing the number–letter switching subtest was estimated using the fitted logistic model consisting of performance on the number sequencing test for patients with AD and a model describing constant probability of completion for patients with MCI. Fitted probabilities ranged from 0.50 to 1.00 for patients with AD and the fitted probability was 0.97 for patients with MCI. The distribution of weights was similar in bilingual and monolingual patients with AD. We reran a complete case analysis of performance on number–letter switching with weights equal to the reciprocal of the fitted probability of performing the subtest. Results were similar to those reported above: There was an interaction between language and diagnosis, with poorer performance among bilingual than monolingual patients with MCI on the number–letter switching subtest.

In summary, results of the TMT in the first test session showed that on the simpler test of number sequencing MCI patients performed better than AD patients (as expected), but there was no effect of language group. On the more complex number–letter switching task, completion times were slower for bilinguals in the MCI group with no language difference in the AD group. Inclusion of lifestyle covariates did not alter these results. Finally, the probability of completing the more complex number–letter switching subtest was predicted by performance on the simpler number sequencing test in AD patients but not in the MCI group, in which almost all patients (97%) successfully completed both tests.

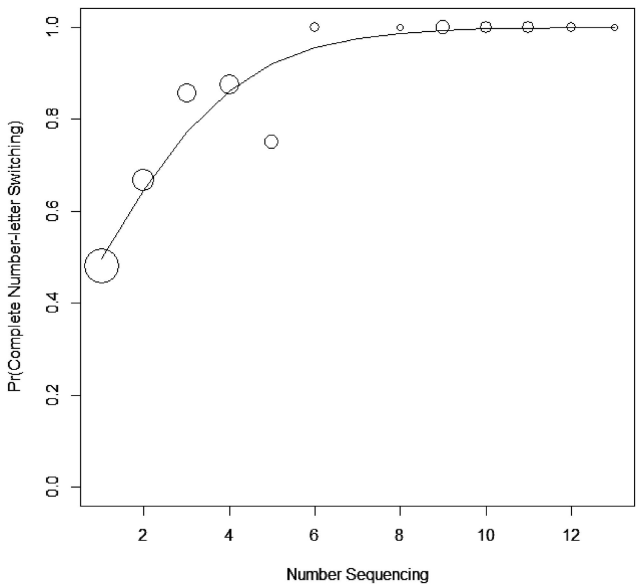

Figure 2. Scatter plot of the proportion of patients with AD who completed the more complex number–letter switching section of the Trail Making Test versus performance on the simpler number sequencing condition. Size of the symbol is proportional to the number of patients at each level of performance. A fitted logistic regression curve is shown.

Color–word interference test. There was a main effect of diagnosis for the color naming ($F(1, 133) = 41.55$, $p < .0001$), inhibition ($F(1, 123) = 20.80$, $p < .0001$), and inhibition-switching ($F(1, 112) = 28.21$, $p < .0001$) subtests with MCI patients obtaining higher scores than AD patients in all cases. No effects of language group and no interaction of language and diagnosis were found on any of these scores. The Stroop effect score, based on the difference between inhibition (incongruent color naming) and color naming revealed higher scores for bilinguals than monolinguals; that is, bilinguals experienced a smaller Stroop effect than monolinguals ($F(1, 117) = 4.58$, $p < .05$). Inclusion of any one of the five lifestyle measures (diet, alcohol, smoking, physical activity, and social activity) in the model did not alter these findings.

Of the 64 patients with AD who performed the simplest color naming subtest, 56 (88%) performed the inhibition subtest, and 46 (72%) performed the inhibition-switching subtest. Logistic regression revealed that among patients with AD the probability of performing the inhibition-switching subtest was associated with performance on the simple color naming condition ($\chi^2 = 8.93$, $p = .003$) and with bilingualism ($X^2 = 6.60$, $p = .01$). These data are plotted in Figure 3. Individuals with poorer performance on color naming showed decreased probability of completing the more difficult subtests, and for monolingual patients the decrease was more rapid. Thus, given equivalent performance on the simplest test, bilinguals were more likely than monolinguals to complete the most difficult subtest, showing that they were able to accomplish more complex tasks even with the same level of performance on simpler related tasks. Patients with MCI tended to complete all subtests if they performed the simplest condition (color naming, $n = 72$; inhibition, $n = 70$, inhibition-switching, $n = 69$). Associations between the simplest and most difficult subtests were not detected among patients with MCI ($p > .63$) and a constant probability model was fit instead.

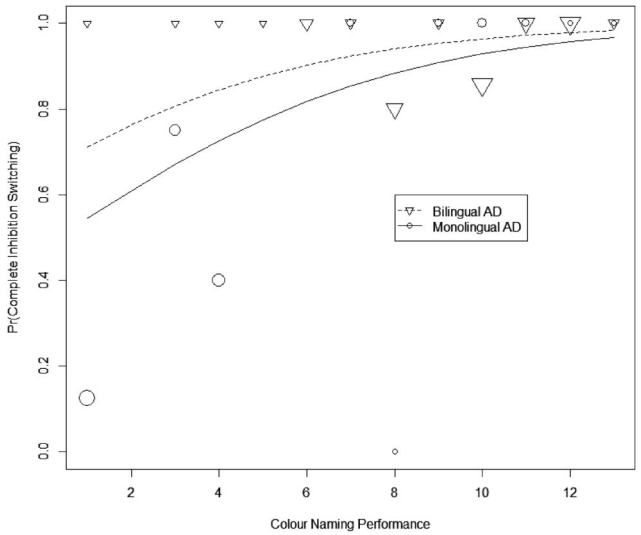

Figure 3. A scatterplot of the proportion of patients with AD who completed the inhibition switching section of the Stroop Test versus performance on the color naming section. Symbols are proportional to the number of monolingual (circle) and bilingual (triangle) patients at each level of performance. Fitted logistic regression curves are shown for each of the monolingual and bilingual patients.

To accommodate the probability of being unable to complete the inhibition-switching subtest as performance on the simpler color naming subtest worsened, we extracted weights equal to the reciprocal of the expected probability of performing the inhibition-switching subtest based on the fitted logistic model. One monolingual patient with AD had the lowest color naming score resulting in a weighting factor of 2.8. Removing this participant, the distribution of weights ranged from 1.01 to 1.87, so we recoded the extreme weight as the trimmed maximum of 1.87. The distribution of weights was similar for bilingual and monolingual patients.

Summarizing the language effects on the CWIT, performance levels showed no difference between monolinguals and bilinguals on color naming, inhibition, and inhibition-switching. However, there was a bilingual advantage on the Stroop effect in both diagnostic groups. With regard to performance on the most complex inhibition-switching task within the AD group, ability to complete this task was predicted by performance on the simple color naming task, but with bilingual participants showing a higher probability than monolinguals of completing the complex task at all levels of color naming ability (see Figure 3).

Verbal fluency test (VFT). There was a main effect of diagnosis with higher scores for MCI patients than AD patients on all verbal fluency scores: letter fluency ($F(1, 137) = 45.23$, $p < .0001$), category fluency ($F(1, 140) = 41.42$, $p < .0001$), and category switching accuracy ($F(1, 140) = 65.51$, $p < .0001$). The analyses found no main effects of language group, and no interactions between language and diagnosis for any of the subtests.

Immigrants were found to perform more poorly than nonimmigrants on letter fluency ($F(1, 137) = 4.17$, $p < .05$). Inclusion of any one of the lifestyle measures (diet, alcohol, smoking, physical activity, and social activity) in the model did not alter the results.

Summarizing the results of the VFT, no differences were detected between monolinguals and bilinguals in either the AD or MCI diagnostic groups, supporting the conclusion that the cognitive levels were equivalent for the two language groups on this task. These results did not change when information about lifestyle was included in the analyses.

Progression of Executive Function Performance Over Time

In order to assess the possibility that language group affected the change in cognitive performance over the months following diagnosis, patients were given the battery of executive tests on two or three occasions with the median time between assessments being 6.2 months for patients with AD (Interquartile Range: 5.8–6.6) and 6.2 months for patients with MCI (Interquartile Range: 5.7–6.8). Data from patients who participated in two or three testing sessions are reported in the Appendix. There are three reasons for the attrition across sessions. The first is that some patients were recruited later in the study and had only completed one or two sessions when data collection terminated. Second, some patients did not agree to participate in subsequent sessions, possibly because they or their caregivers believed they were no longer able to complete the tasks. Third, some patients may have died over the course of the study. In general these attrition rates were similar

between language groups and we accommodated drop-out mechanisms that were associated with MMSE (described below).

In order to assess ongoing performance on the tests we fitted a mixed effects model to each of the D-KEFS outcome measures observed across sessions using the Mixed procedure in SAS 9.1. Variables included in the model were bilingualism, assessment session, and the interaction between them. Intercept and slope over time were modeled as random effects. In this section we report only results for the slope estimate because the intercept reflects performance at the first testing session which is described above. Immigration status was included in all models and only substantial alteration of the fitted model due to inclusion of an immigration × session cross-product term is reported here. An unrestricted correlation matrix was used to describe associations among the three sessions. Models were fit for each of the four (language × diagnosis) groups separately.

Slope estimates are summarized in Table 4. The majority (27/36) of measures yielded nominally negative mean slopes, showing that performance generally declined over the 1-year period following diagnosis, despite the relatively short time intervals and the fact that the same tests were repeated on each occasion. None of the analyses revealed an interaction between language and testing session; that is, there were no cases of differential decline in performance as a function of language group. Accordingly, the significance of the slope was assessed after collapsing over language, and the significant values for language pairs are shown in bold in Table 4.

Trail making test (TMT). No significant changes over sessions were observed for patients with either MCI or AD on number sequencing, $|t| < 1$. For number–letter switching the MCI group showed no significant change but the AD group showed a decrease over time ($t(26) = -2.43$, $p < .05$).

Unlike MCI patients who generally returned for subsequent tests, many AD patients dropped out from one session to the next. Thus, for patients with AD who had observations in more than one session, we assessed the *probability of returning* to be assessed at the third session from scores obtained in the first session. This probability was higher for patients who had higher MMSE scores ($\beta = 0.20$, $p = .03$). We found no indication of a difference in probability of returning based on bilingualism ($p = .50$), nor did we find alteration of the MMSE effect based on bilingualism in these patients.

When we weighted the longitudinal analysis by the reciprocal of the probability of participant retention, we continued to observe no change over time for patients with AD on number sequencing, $|t| < 1$. However, the decrease in number–letter switching score over time was attenuated for the AD group under attrition weighting ($t(26) = -2.01$, $p = .06$).

Color–word interference test (CWIT). CWIT performance was found to deteriorate on the color naming condition for both MCI patients ($t(34) = -2.15$, $p < .05$) and for patients with AD ($t(39) = -2.04$, $p < .05$). When we weighted the longitudinal analysis of CWIT performance for patients with AD by the reciprocal of the probability of participant retention, deterioration on color naming was attenuated ($t(39) = -1.90$, $p = .07$). None of the other three measures in this group (inhibition, Stroop effect, and inhibition switching) showed significant declines over the 1-year period.

Verbal fluency test (VFT). Patients with MCI showed decline over time on two of the subcomponents of this task: letter fluency ($t(54) = -3.28$, $p = .002$) and category switching accuracy ($t(53) = -2.42$, $p = .02$). Patients with AD showed a decline only on the category fluency subtest of the VFT ($t(58) = -2.63$, $p = .01$). When the longitudinal analysis was weighted by the reciprocal of the probability of participant retention, patients with AD continued to show a decline on category fluency ($t(58) = -2.71$, $p = .009$).

To summarize, declining scores over testing sessions were observed on several of the subtests of the D-KEFS measures. For TMT, declines were observed for number–letter switching (AD only); for CWIT, declines were observed for color naming in both diagnostic groups; and for VFT, declines were observed for letter fluency and category switching accuracy for the MCI group, and for category fluency for the AD group. Of major importance in the present context, there were no cases of differential decline between monolingual and bilingual patients.

Table 4
Slope (and Standard Deviation) for Each Variable Across Three Testing Sessions

	MCI				AD			
	Monolingual		Bilingual		Monolingual		Bilingual	
Task measure	N	*M* (*SD*)	N	*M* (*SD*)	N	*M* (*SD*)	N	*M* (*SD*)
Trails								
Number sequencing	21	−0.71 (1.37)	17	0.38 (3.58)	25	−0.38 (1.89)	20	0.18 (2.51)
Number–letter switching	21	−0.31 (1.01)	17	0.18 (1.95)	20	**−1.40** (3.34)	15	**−1.17** (2.38)
Color–word interference								
Color naming	21	**−0.19** (1.15)	17	**−0.68** (2.77)	24	**−0.19** (1.66)	20	**−0.55** (2.49)
Inhibition	21	0.05 (1.11)	17	−0.26 (2.77)	22	−0.45 (2.08)	17	−0.44 (2.76)
Stroop effect	21	0.12 (0.99)	16	0.34 (3.10)	22	−0.30 (2.53)	17	0.15 (2.28)
Inhibition switching	21	0.02 (1.68)	17	−0.44 (3.46)	19	−0.84 (2.30)	16	−0.12 (2.05)
Verbal fluency								
Letter fluency	21	**−0.67** (1.64)	17	**−0.97** (2.34)	26	−0.23 (2.41)	18	−0.72 (1.13)
Category fluency	21	−0.43 (1.49)	17	0.26 (2.71)	26	**−0.88** (1.61)	18	**−0.78** (1.25)
Category switching	21	**−1.64** (3.47)	17	**−0.47** (2.74)	26	−0.02 (2.12)	18	−0.11 (2.17)

Note. Significant slopes (within each diagnostic group) are shown in bold print.

Discussion

The results from the present study address each of the three questions raised in introduction. First, as in previous studies, bilinguals tended to be older than monolinguals when first presenting symptoms and when they first attended the clinic with AD, a difference that was extended to MCI and shown to be independent of lifestyle factors such as diet and exercise. Second, the general absence of differences between monolinguals and bilinguals on the detailed executive function tests within each diagnostic group at the time of the first clinic visit (see Table 3) shows that the patients in both languages groups were at comparable cognitive levels; bilinguals were not waiting longer to seek diagnosis and treatment for symptoms. This finding confirms previous reports of equivalent cognitive levels between monolingual and bilingual participants, despite bilinguals being older at the time of diagnosis. Finally, no differences were found in the rate of cognitive decline between the language groups. Because of considerable attrition over the testing sessions, these last results need to be interpreted with some caution. However, our analysis based on statistical weighting of the probability of participant retention is consistent with the conclusion that later onset is not associated with a detectably more rapid decline in this sample.

Consider each of these findings in turn. First, the present data are consistent with previous reports regarding the initial onset of dementia (Bialystok et al., 2007; Craik et al., 2010) in several respects. There was a significant effect of bilingualism on both age of onset and age of first clinic appointment such that bilinguals diagnosed with MCI or AD were older than their monolingual counterparts when they began to show symptoms (by 4.7 years and 7.3 years, respectively), and when these symptoms reached clinical significance resulting in their first visit to the memory clinic (by 3.5 years and 7.2 years, respectively). These values for the bilingual advantage in a clinical context are higher than those reported previously; however, it should be noted that the present sample sizes are relatively small—between 35 and 40 per group—therefore, the exact ages should be treated cautiously. Although 47% of the AD patients were included in the report by Craik et al. (2010) reporting later symptom onset for bilinguals than monolinguals, the present study extends the results for those patients by confirming their ages through the Onset of Symptoms questionnaire and qualifying their background through the Lifestyle Questionnaire.

Bilinguals were different from monolinguals in two respects that might have confounded these results. First, bilinguals were more likely than monolinguals to be immigrants, leading to the possibility that immigration status and not bilingualism was responsible for later onset. However, that possibility is ruled out by the analyses showing no association between immigration status and onset age (partial correlation, $r = -0.02$), and no substantive change in the effects of language group and diagnostic group on onset and clinic appointment ages when immigration status was included in the model. That is, immigration status had no systematic effect on age of onset or age of first clinic visit, and inclusion in the model did not attenuate the positive effects of bilingualism. Consistent with this result, a follow-up analysis by Schweizer, Craik, and Bialystok (2013) in which they compared only nonimmigrant monolinguals and bilinguals produced the same results as were reported in the original study (Schweizer et al., 2012) that included a majority of immigrants in the bilingual sample. Second, bilinguals had slightly less formal education than monolinguals. Again, including years of education into the analysis of age of onset and age of first clinic visit did not reduce the effect of bilingualism. Although factors such as education and socioeconomic status remain relevant in determining onset of dementia, bilingualism nonetheless continues to exert an influence over and above these factors. Moreover, an assessment of lifestyle factors ruled out potential confounds between bilingualism and other circumstances that might be associated with delay in symptom onset for dementia.

To our knowledge, only one previous study has investigated the potential influence of bilingualism in onset of symptoms of amnestic MCI (Ossher et al., 2013); the present study extends those results by showing a significant influence of bilingualism in delaying symptoms of MCI in a heterogeneous group of MCI patients. Therefore, the present results in conjunction with the previous literature support the conclusion that symptoms of cognitive decline are postponed in bilingual individuals.

The lifestyle factors produced mixed results, with the monolingual and bilingual groups each having healthier outcomes on some variables, in a pattern that differed across diagnoses. Including variables that showed group differences as covariates for the AD group reduced the delay effect somewhat, but not enough to eliminate its statistical significance. The same variables included as covariates for the MCI group had no substantive effect. These results support our argument that bilingualism per se, not other factors associated with it, should be considered one source of potential cognitive reserve because other lifestyle factors exercise minimal moderating effects on the delay on age of onset.

The second issue is the cognitive level of patients at the time they seek treatment. On global levels of cognitive status, bilinguals had marginally lower scores than monolinguals on MMSE ($p = .05$) and BNA ($p = .07$) when immigration status was included in the model. However, these test scores are not corrected for age, and the bilinguals were significantly older than the monolinguals. Additionally, the BNA has a substantial verbal component, requiring patients, for example, to recall word lists and bilinguals generally perform more poorly than monolinguals on such tasks (e.g., Bialystok, Craik, & Luk, 2008). The slightly (but not significantly) lower performance by bilinguals on this task is therefore not surprising.

The novel feature in the present study was the inclusion of detailed measures of executive functioning that were administered to all patients. These tests provide more precise information about cognitive level than do the global measures commonly used in this type of research, such as MMSE. The results from these tests support the interpretation that bilinguals were not simply delaying assessment for cognitive difficulties but were functioning at similar cognitive levels as monolinguals when treatment was sought. On all three tests, there were very few main effects of language or interactions between language and diagnosis. There were some exceptions, including worse bilingual performance for the number–letter switching condition of the TMT in MCI but not AD patients. However, bilinguals showed a significantly smaller Stroop effect in the CWIT in both groups. Even more striking, bilinguals who had poor performance in the simple subtests of the CWIT had higher probability of completing the more challenging subtests than did their poorly performing monolingual counterparts—that is, they were able to complete harder subtests despite

having approximately the same low levels of baseline performance as their monolingual peers (see Figure 3). This bilingual advantage on the Stroop effect is consistent with previous claims of a bilingual advantage in situations tapping attentional control in general (e.g., Bialystok et al., 2004) and the Stroop effect in particular (Bialystok et al., 2008). Overall, the results from the D-KEFS battery highlight the comparability between language groups in scores for these tests in the first testing session. This pattern strongly supports the conclusion that cognitive performance, and specifically executive functioning, is comparable for the two language groups despite their age difference. Again, these data support our interpretation that there is a substantial delay in symptom onset that does not reflect an artifact of delaying assessment. Were bilinguals simply waiting longer to seek physician assessment, we would expect their cognitive function to be poorer, owing to more years of decline below clinically significant impairment in function.

Finally, the third question is the rate of decline in cognitive functioning following diagnosis. The analysis we used to evaluate the slope of the scores across testing sessions was adjusted to compensate for drop-outs in that it assigned lower weight to participants who returned to complete subsequent sessions than to those who did not. Presumably the ability to complete three testing sessions is associated with higher cognitive levels, therefore, the results are thought to underestimate the deterioration of performance across these sessions. The important question, however, is whether these slopes differed for the two language groups and the answer for all three tasks is that they do not. For the TMT, five of the eight slope values were nominally negative (showing a decline in performance over time), but the decline was significant only in the AD group on number–letter switching. In the CWIT, color naming dropped significantly in both diagnostic groups, reflecting perhaps a general slowing effect. Of the 12 remaining measures, only seven gave negative slopes. Finally, in the VFT, there was significant decline in performance across sessions, for MCI patients on letter fluency and category switching and for AD patients on category fluency, but none of these effects included language group as a factor. Therefore, the overall decreasing scores across the three testing sessions showed remarkably few effects of language group. The VFT measures showed the most consistent declines of the D-KEFS tests, with 11 of the 12 slopes being negative. Thus, in spite of being older at the time of diagnosis, bilingual and monolingual patients in the present sample obtained comparable scores on executive function tests at time of diagnosis and declined at comparable rates over time as the disease progressed. The small number of patients completing all three sessions, however, means that this conclusion must be taken with some caution.

In summary, our results replicate the documented delay for bilinguals in the onset of clinically significant symptoms of AD and its precursor condition, MCI. Additionally, the results demonstrate that this delay is not associated with assessments of executive function. Finally, the evidence is inconsistent with the hypothesis that a later age of clinically significant onset is associated with a subsequently faster deterioration of cognitive abilities. These results have a number of important clinical implications. First, language background is an important variable to consider when evaluating patients, as superior executive abilities may compensate for, or mask other cognitive declines. Second, the present results contribute to a mounting literature suggesting that there is a late-life benefit from early bilingual exposure and continued bilingual practice. Because the delay in the onset of symptoms is associated with a delay in the onset of medical treatment, home care, and hospitalization, there are potentially substantial health care savings associated with such a delay in the onset of symptoms. Future research examining the influence of delayed onset and progression of cognitive decline can quantify these financial implications. The delay documented here is approximately 6 years, similar to previous reports. These 6 years may amount to 5 additional years of independent living and good quality of life for older adults. Extending the number of high quality of life years is a major goal of current pharmaceutical and cognitive training interventions. If cognitive reserve factors such as bilingualism can achieve this type of prolonged good quality of life, investment in research to understand the effects of bilingual life experience and in programs to harness the advantages of bilingualism may prove invaluable.

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Appendix A

MCI Patients

*Number of Participants (N), Means, and Standard Deviations (*SD*) for Scores on The D-KEFS Tests Across Three Testing Sessions for MCI Patients*

	Testing sessions					
	1		2		3	
MCI patients	N	Mean (*SD*)	N	Mean (*SD*)	N	Mean (*SD*)
Trails						
Number sequencing						
Monolingual	20	10.50 (3.4)	20	9.40 (4.1)	15	9.47 (2.7)
Bilingual	17	8.94 (5.2)	17	9.53 (3.9)	7	9.00 (1.8)
Number–letter switching						
Monolingual	20	10.85 (1.5)	19	10.68 (2.3)	15	9.73 (2.5)
Bilingual	17	8.35 (3.5)	16	9.00 (3.3)	7	8.71 (1.8)
Color–word interference						
Color naming						
Monolingual	20	8.70 (2.9)	20	8.55 (3.1)	15	8.40 (2.8)
Bilingual	17	9.00 (3.3)	17	8.41 (2.1)	6	7.00 (3.0)
Inhibition						
Monolingual	20	9.30 (2.5)	19	9.16 (2.9)	15	9.20 (3.3)
Bilingual	17	9.65 (3.4)	17	9.41 (3.5)	6	7.50 (3.7)
Stroop effect						
Monolingual	20	10.40 (2.7)	19	10.00 (2.0)	15	10.73 (2.1)
Bilingual	16	10.69 (2.3)	16	10.75 (3.4)	5	11.00 (1.7)
Inhibition switching						
Monolingual	20	8.40 (3.2)	19	9.21 (3.2)	15	8.07 (3.0)
Bilingual	17	8.94 (4.0)	17	8.24 (3.4)	6	7.33 (3.4)
Verbal fluency						
Letter fluency						
Monolingual	20	11.40 (3.6)	20	11.05 (3.9)	15	9.60 (4.5)
Bilingual	17	10.88 (3.9)	17	9.88 (3.7)	6	8.50 (1.4)
Category fluency						
Monolingual	20	8.35 (2.4)	20	7.95 (2.9)	15	7.20 (2.2)
Bilingual	17	8.29 (3.1)	17	8.59 (2.5)	6	7.83 (3.0)
Category switching						
Monolingual	20	9.20 (3.2)	20	7.90 (4.2)	15	7.07 (3.8)
Bilingual	17	8.94 (2.6)	16	7.75 (2.8)	6	7.83 (3.0)

(*Appendices continue*)

Appendix B

AD Patients

*Number of Participants (N), Means, and Standard Deviations (*SD*) for Scores on The D-KEFS Tests Across Three Testing Sessions for Alzheimer's Disease (AD) Patients*

	Testing sessions					
	1		2		3	
AD patients	N	Mean (*SD*)	N	Mean (*SD*)	N	Mean (*SD*)
Trails						
Number sequencing						
Monolingual	24	4.17 (3.9)	24	4.17 (3.4)	12	4.25 (3.5)
Bilingual	20	4.50 (4.1)	19	5.16 (3.1)	8	5.13 (3.0)
Number–letter switching						
Monolingual	18	4.72 (3.9)	17	3.12 (2.8)	10	4.30 (3.6)
Bilingual	14	5.86 (3.7)	13	4.92 (3.6)	3	7.00 (1.0)
Color–word interference						
Color naming						
Monolingual	24	5.46 (4.0)	22	5.45 (4.1)	11	6.27 (4.3)
Bilingual	19	4.58 (4.0)	20	3.95 (3.3)	7	2.14 (1.7)
Inhibition						
Monolingual	21	5.67 (4.5)	19	6.05 (4.2)	10	6.10 (4.6)
Bilingual	17	6.47 (3.9)	15	6.53 (3.9)	6	4.67 (2.6)
Stroop effect						
Monolingual	21	9.67 (3.6)	19	9.95 (3.5)	10	9.30 (2.2)
Bilingual	17	11.47 (3.5)	15	11.87 (2.8)	6	12.33 (3.2)
Inhibition switching						
Monolingual	14	5.21 (4.5)	14	4.64 (4.4)	6	5.17 (4.5)
Bilingual	16	4.94 (4.1)	13	5.54 (4.1)	3	3.33 (2.1)
Verbal fluency						
Letter fluency						
Monolingual	26	7.88 (4.5)	24	7.96 (3.9)	11	9.00 (4.5)
Bilingual	18	7.06 (4.4)	18	6.33 (4.2)	7	7.00 (2.8)
Category fluency						
Monolingual	26	5.73 (2.9)	24	4.71 (3.0)	11	6.09 (3.3)
Bilingual	18	4.67 (3.0)	18	4.00 (2.6)	7	3.71 (1.6)
Category switching						
Monolingual	26	4.73 (3.5)	24	4.88 (3.1)	11	5.09 (2.4)
Bilingual	18	4.44 (2.3)	17	4.76 (3.6)	7	4.00 (2.4)

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