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Does Bilingualism Influence Cognitive Aging?

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Recent evidence suggests a positive impact of bilingualism on cognition, including later onset of dementia. However, monolinguals and bilinguals might have different baseline cognitive ability. We present the first study examining the effect of bilingualism on later-life cognition controlling for childhood intelligence. We studied 853 participants, first tested in 1947 (age 511 years), and retested in 2008–2010. Bilinguals performed significantly better than predicted from their baseline cognitive abilities, with strongest effects on general intelligence and reading. Our results suggest a positive effect of bilingualism on later-life cognition, including in those who acquired their second language in adulthood.

Subjects and Methods

Participants
LBC1936 Wave 1 testing included 1,091 participants of the Scottish Mental Survey 1947.6,10 Of those, 866 returned for the Wave 2 assessment in 2008–2010,7 and 853 (410 female, 443 male, age = 70.91–74.15 years, mean = 72.49, standard deviation = 0.71) completed the bilingualism questionnaire. Thirteen subjects, born abroad of British parents, moved to Scotland before the age of 11 years. The analysis conducted with and without these participants showed small differences and similar effect sizes, so we report the results from the full sample. A power analysis (G*Power 3.1.511), with a bilingualism effect expressed as a partial $R^2$ of 0.02 in a multiple regression model of 9 predictors, required a sample of 640 for a power of 0.95, deeming our sample sufficient.

Assessment of Bilingualism
The participants were asked in a questionnaire whether they had learned any languages other than English (L2), how many, at what age, and how often they used them (daily/weekly/monthly/less than monthly/never) in 3 domains: conversation/reading/media. We classified as bilingual participants who reported being able to communicate in L2.

Cognitive Tests

GENERAL FLUID-TYPE INTELLIGENCE (G-FACTOR). This consisted of a composite of 6 nonverbal tests: Letter–Number Sequencing, Matrix Reasoning, Block Design, Digit Symbol and Symbol Search from the Wechsler Adult Intelligence Scale-III, UK edition (WAIS-III), and Digit Span Backward from the Wechsler Memory Scale-III, UK edition (WMS-III).

MEMORY. This consisted of a composite of Logical Memory (immediate/delayed), Spatial Span (forward/backward), Verbal Paired Associates (immediate/delayed), Digit Span Backward from the WMS-III, and Letter Number Sequencing from the WAIS-III.
SPEED OF INFORMATION PROCESSING. This consisted of a composite of Symbol Search and Digit Symbol (WAIS-III), visual inspection time, and simple and choice reaction times.12

MORAY HOUSE TEST. This is a paper and pencil general cognitive test, including mainly verbal reasoning tasks13 (repetition of the test from 194710).

VOCABULARY/READING. The National Adult Reading Test (NART)14 examined the pronunciation of 50 irregular English words.

VERBAL FLUENCY. Participants were asked to say as many words as possible beginning with letters C, F, and L, with a 1-minute time limit for each.

Data Analysis
As CI is predictive of cognitive functioning in old age,15 we adjusted for it when examining the effects of bilingualism on cognitive performance. Outcome variables were Winsorized at the 1st percentile and standardized with zero mean and unit standard deviation. Each was separately modeled as the outcome of multiple linear regression in which the focal predictor was a given variable related to bilingualism, controlling for exact age at testing, sex, and social class (subject’s and their father’s).

TABLE 1. The Association between Different Types of Bilingualism and Cognitive Ability at Age 73 Years

| Outcome Variables | Age of Acquisition | Number of Languages | Frequency of Use |
|-------------------|--------------------|---------------------|------------------|
|                   | Early/Late         | 2/Multi             | Passive/Active   |
|                   | Estimate SE        | Estimate SE         | Estimate SE      |
|                   | Pr>|t|               | Pr>|t|                | Pr>|t|              |

The table shows regression estimates for 6 cognitive outcome variables (g-factor, g-memory, g-speed, MHT, NART, VFT) and different types of bilingualism (early vs late acquisition, bi- vs multilingualism, passive vs active). The first row for each outcome is the intercept of the monolingual reference line (see text). The second and third rows show the change in intercept relative to the reference (hence the effect of different types of bilingualism). Where interactions were significant, each marginal main effect represents the outcome change per unit of the covariate with other variables held constant at their respective centered values.

Age of second language acquisition: Early = acquired before age 18 years; Late = acquired after age 18 years. Number of languages acquired: 2 = 2 languages (bilingual); Multi = ≥3 (multilingual). Frequency of use of the second language: Passive = no active use in the past 5 years; Active = active use in the past 5 years.

*aSignificant effects.
g-Factor = general fluid intelligence factor; g-Memory = memory factor; g-Speed = processing speed factor; MHT = Moray House Test; NART = National Adult Reading Test; SE = standard error; VFT = Verbal Fluency Test.

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Three bilingualism-related variables, graded into 3 levels, were considered separately: age of acquisition of L2 (never/early/late), number of languages (monolingual/bilingual/multilingual), and the frequency of L2 usage (no second language/no active use/active use). A dummy variable regression model was specified to estimate the effects of bilingualism variables upon the relationship between cognition at age 70 years and CI at age 11 years, adjusted for age at testing, sex, and social class (subject’s and their father’s). The dummy variables representing levels of bilingualism were coded so as to measure effects relative to a monolingual reference. The model included the main
effect of bilingualism and its interaction with CI. We interpreted these effects as additions respectively to the intercept and slope of the predicted relationship between cognition at age 70 years and CI (Fig). Where the interaction with CI (intelligence quotient [IQ] at age 11 years) was significant, we report effects of bilingualism at 3 points along the scale of IQ at age 11 years (mean/5th/95th percentile) by refitting the models with CI centered on these 3 points respectively.

Results

Two hundred sixty-two participants reported having learned at least 1 language other than English to a degree allowing them to communicate. One hundred ninety-five learned the second language before the age of 18 years (of those, 19 before the age of 11 years), and 65 thereafter. One hundred sixty individuals knew 2, 61 knew 3, 16 knew 4, and 8 knew 5 languages (the last 3 groups were merged into "multilinguals"). One hundred seventy were using only English in their everyday life, whereas 90 used their second language in at least in 1 of the 3 domains.

Table 2. Interactions between the Types of Bilingualism and Childhood Intelligence (IQ at Age 11 Years) in the Prediction of Cognitive Performance at Age 73 Years

| Bilingual Type | g-Factor | g-Memory | g-Speed | MHT     | NART    | VFT     |
|----------------|----------|----------|---------|---------|---------|---------|
| Acquired       |          |          |         |         |         |         |
| Early          | 0.01 (0.10) | 0.02 (0.01)^a | 0.01 (0.08) | 0.00 (0.8) | -0.01 (0.29) | 0.01 (0.26) |
| Late           | -0.01 (0.11) | 0.00 (0.83) | -0.01 (0.28) | -0.02 (0.02)^a | -0.01 (0.18) | -0.01 (0.38) |
| Number         |          |          |         |         |         |         |
| 2              | -0.00 (0.82) | 0.01 (0.10) | 0.00 (0.86) | -0.00 (0.54) | -0.01 (0.16) | 0.01 (0.18) |
| Multi          | 0.01 (0.31) | 0.01 (0.22) | 0.01 (0.29) | -0.01 (0.29) | -0.01 (0.08) | 0.00 (0.8) |
| Usage          |          |          |         |         |         |         |
| Passive        | 0.00 (0.50) | 0.01 (0.09) | 0.01 (0.38) | 0.00 (0.87) | -0.01 (0.29) | 0.00 (0.92) |
| Active         | 0.00 (0.96) | 0.02 (0.08) | -0.01 (0.60) | -0.02 (0.03)^a | -0.01 (0.09) | 0.01 (0.44) |

The table shows the estimated interaction effects between IQ at age 11 years and the dummy variables representing the bilingualism-related variables. Each bilingualism variable had 3 levels. The table shows comparisons between 2 of them and the corresponding reference level representing monolingualism. The table shows standardized effects with probability values in parentheses.

^aSignificant interaction effects. The 3 relevant interactions are illustrated in the Figure.

g-Factor = general fluid intelligence factor; g-Memory = memory factor; g-Speed = processing speed factor; IQ = intelligence quotient; MHT = Moray House Test; NART = National Adult Reading Test; VFT = Verbal Fluency Test.

FIGURE 1: (A–C) Interaction between bilingualism, childhood intelligence quotient (IQ), and cognitive performance at age 73 years. (A) Memory in relation to the age of acquisition of the second language. (B) Moray House Test (MHT) in relation to the age of acquisition of the second language. (C) MHT in relation to the pattern of use of the second language. The abscissa in all 3 graphs is the IQ measured at age 11 years. The ordinate is g-memory (A) and MHT (B, C). (A, B) Never = monolingual group; Early = before age 18 years; Late = after age 18 years. (C) Mono = monolingual; Passive = second language not used in the past 5 years; Active = second language used actively in the past 5 years.
with low intelligence from late acquisition, but neither group showed negative effects. Early and late acquisition of a second language might have different effects on frontal executive functions, possibly modulated by baseline intelligence.

Knowing 3 or more languages produced stronger effects than knowing 2. This variable has yielded contradictory results in previous studies and requires further research. Little difference was found between active and passive bilinguals, possibly due to low frequency of second language use, even in “active bilinguals.” However, it is conceivable that acquisition of a second language leaves lasting cognitive traces independently of its subsequent use. If bilinguals automatically and unconsciously activate both languages, they constantly need to select, monitor, and suppress linguistic information, stimulating frontal executive functions.

The observed effect sizes are comparable to those reported for other factors contributing to differences in cognitive ability and cognitive change, such as the effect of variation in the gene for apolipoprotein E, physical fitness, and (not) smoking. Accordingly, the interpretation of our data should be in terms of cognitive epidemiology, rather than clinical application to an individual. As a small reduction in a population’s blood pressure can have a sizeable effect on the number of strokes despite blood pressure accounting for only a small reduction in stroke, a modest change in the proportion of people who learn 1 or more extra languages could have a population effect on cognitive pathology rates.

Our study has limitations. The knowledge of language was defined by a questionnaire, not proficiency. Only few participants acquired their second language before age 11 years, so we could not study the classical cases of parallel, perfect, early acquisition of both languages. However, this limitation is also a strength. Millions of people across the world acquire their second language later in life: in school, university, or work, or through migration or marriage to a member of another linguistic community. Many never reach native-like perfection. For this population, our results are particularly relevant; bilingualism in its broad definition, even if acquired in adulthood, might have beneficial effects on cognition independent of CI.

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Authorship

T.H.B. determining research questions, drafting bilingualism questionnaire, analysis planning, data interpretation, manuscript revision; J.J.N.: data collection and analysis, manuscript revision; M.M.A.: statistical analysis, manuscript revision; I.J.D.: analysis planning, study design, study coordination, revising bilingualism questionnaire, analysis planning, data interpretation, manuscript revision.

Potential Conflicts of Interest

Nothing to report.

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