The relationship of bilingualism compared to monolingualism to the risk of cognitive decline or dementia: a systematic review and meta-analysis

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Abstract:

BACKGROUND: Bilingualism may contribute to cognitive reserve, protect against cognitive decline and delay the onset of dementia.

OBJECTIVE: We systematically reviewed evidence about the effect of bilingualism on subsequent cognitive decline or dementia.

METHODS: We searched electronic databases and references for longitudinal studies comparing cognitive decline in people who were bilingual with those who were monolingual and evaluated study quality. We conducted meta-analyses using random effects models to calculate pooled odds ratio of incident dementia.

FINDINGS: We included 13/1,156 eligible articles. Meta-analysis of prospective studies of the effects of bilingualism on future dementia gave a combined Odds Ratio of dementia of 0·96 (95% CI 0·74-1·23) in bilingual participants (n = 5,527) compared to monolinguals. Most retrospective studies found that bilingual people

were reported to develop symptoms of cognitive decline at a later age than monolingual participants.

INTERPRETATION: We did not find that bilingualism protects from cognitive decline or dementia from prospective studies. Retrospective studies are more prone to confounding by education, or cultural differences in presentation to dementia services and are therefore not suited to establishing causative links between risk factors and outcomes.

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Key words: Bilingualism; cognitive decline; dementia; prospective cohort studies

Background

As the number of people with dementia continues to rise worldwide, with the accompanying social and healthcare burden [1], there is growing interest in factors that may delay or prevent the onset of cognitive decline and dementia [2]. It is recommended that people should learn multiple languages to delay the onset of dementia [3].

Cognitive reserve, defined as resilience to neuropathological damage [4], has been shown to delay dementia onset, possibly by enhancing neural networks [5] or improving specific cognitive strategies [6]. Being fluent in two or more languages may contribute to cognitive reserve [7], and this may be a specific effect, rather than the general effect of more education, because switching languages possibly leads to an enhanced executive function rather than enhancing medial temporal memory circuitry [8]. Bilingualism is, however, complex and heterogeneous and is linked to factors, such as education, that can also affect risk of dementia [9].

Retrospective studies have found that bilingualism delays the onset of dementia by around four years [7;10;11]. Some prospective studies have similarly found a protective effect of learning additional languages [12-14] while others have not [15-17]. We therefore systematically reviewed the literature in this field to clarify the link between bilingualism and cognitive decline or dementia.

Method

Search strategy: We searched PubMed (from 1946) and Web of Knowledge (from 1900) until 23rd November 2016, using search terms “bilingual*” OR “language” AND

"dementia", "AD", "Alzheimer*" OR "cognit*". We placed no limits on language or date of publication. We combined the search results and removed duplicates. We searched the references of included papers for further papers of interest.

Inclusion criteria: We included primary research published in peer-reviewed publications in any language which fulfilled the following three criteria:

- included people who spoke more than one language and a comparison group who did not.
- reported on cognitive function in participants not diagnosed with pre-existing neurological disorders.
- reported either a quantitative cognitive outcome measure on a validated cognitive test or incident dementia or incident mild cognitive impairment.

Exclusion criteria:

- Meeting abstracts and letters.
- Comparisons between multilinguals and bilinguals with no monolingual group.

Searches and inclusion of papers: One of the authors (NM) conducted the searches and read all titles and abstracts. She read papers of studies with abstracts or titles that met inclusion criteria in full to decide whether they met inclusion criteria and discussed those which there were any questions about with the other authors.

Quality assessment: Two of the authors (NM and AS) independently read included papers and assessed their quality using an eight-point checklist from the Newcastle-Ottawa scale for non-randomised studies [18] (see Appendix Table 1). The questions were: Was the cohort representative of a defined population? Was the exposure

(language status) accurately defined and measured? Was outcome clearly defined and measured? Have the authors adjusted for all important confounding factors? Was follow-up complete (>70%) (including death as follow-up)? Was follow-up long enough (>5 years)?

We pre-specified that we would categorise as higher quality studies those with a definition of or assessment of bilingualism, with reliable and valid cognitive outcome measures and adjusted for important confounders known to be associated with cognitive outcomes such as age, sex, education, vascular risk factors and other potential confounders such as immigration and socio-economic status. This was to ensure that higher quality studies had valid measures of the exposure and outcome and the findings could not be accounted for by known confounders. We contacted authors for further information regarding their studies if this was not clear, in order to be able to assess quality accurately.

Analysis: If studies had multiple waves of data collection, we examined data from after the five year follow-up. We planned to combine data from three or more studies where possible using a meta-analysis. We extracted raw data of numbers of people diagnosed with dementia in the respective bilingual and non-bilingual groups and combined unadjusted odds ratios from included studies, to calculate an overall unadjusted risk of developing dementia in bilinguals versus non-bilinguals using random effects models meta-analyses [19] with RevMan version 5·3 software. This approach is suitable for combining studies from heterogeneous populations and when different binary outcome measures are reported as it accounts for between-study variance [20].

Results

The PRISMA diagram in Figure 1 shows our search strategy results. We included 13 of 1154 articles, reporting 13 separate studies fulfilling our criteria. Four studies were excluded after the full paper was retrieved – one because there was no record of whether or not participants spoke more than one language, [14], another because it did not include a monolingual comparator group [21] and two because they compared bilingual participants with multilingual rather than monolingual participants [12;13]. Of the included studies, five were prospective and reported in Table 1 and eight were retrospective or cross-sectional and are reported in Table 2. We contacted and obtained additional information on follow-up rates and outcomes from authors of two included papers. Quality scores for each item in all studies are given in Appendix Table 1.

Prospective studies (see table 1)

The prospective studies all recruited a random sample of community-dwelling participants without baseline cognitive impairment [15-17;22;23]. Bilingualism was defined as the self-reported ability to communicate in two languages. One study validated reports of bilingualism with a reading test [17] but used self-defined proficiency in primary analyses. The outcome, measured at least five years later, was either cognitive testing or formal diagnostic assessments. One study interviewed people in English and defined them as native English speakers (NES) or non-native English speakers (n-NES) with the latter group being asked if they spoke another language and how often they spoke it [23]. This study may therefore have included some bilingual native English speakers in the 'monolingual' group.

Four higher quality studies used dementia diagnosis as the outcome [15-17;23]. All of these studies made the diagnosis by using cognitive screening tests then further

cognitive assessment if scores were low. One of these studies calculated an odds ratio for developing dementia, adjusted for age, sex, education and subjective memory loss [16]. The others compared mean age of dementia diagnosis [15], hazard ratio for incident dementia [23] and Cox regression on rate of dementia conversion [17] respectively. None of these studies found significant differences between bilingual and monolingual participants.

These outcomes were too heterogeneous to be combined in a meta-analysis but all the papers contained raw data of numbers of people diagnosed with dementia in the respective bilingual and non-bilingual groups. We extracted this data and conducted a meta-analysis of 5527 participants. The meta-analysis combined unadjusted odds ratios from included studies to calculate an overall unadjusted odds ratio of developing dementia in bilinguals versus non-bilinguals of 0·96 (95% CI 0·74-1·23) (see Figure 2), which indicates no advantage of bilingualism in protecting against dementia compared to monolingualismIn the studies included in the meta-analysis, two reported bilinguals to have received more education, one found no significant difference between education of bilinguals and monolinguals and one reported that they received less education although reading level and therefore English proficiency, was similar in both groups.

Another, lower quality, study did not control for any confounding factors (e.g. sex, education) [22]. This study used scores on validated tests of different cognitive functions such as verbal fluency and memory. It found that those who were bilingual had higher scores on the tests of premorbid cognitive functioning; National Adult Reading Test [24] and General Fluid-Type Intelligence (G-factor) than monolinguals.

Retrospective studies (see Table 2)

The included retrospective studies were generally set in memory clinics or other specialist centres where people with memory complaints came for assessment. Trained specialists made diagnoses of dementia or mild cognitive impairment (MCI) according to validated diagnostic criteria. Most of the participants in these studies had come seeking help for cognitive complaints. One study recruited participants by advertising to the public and specifically requesting physician referrals of people with memory complaints [25] and participation required subjective memory complaints. Bilingualism was defined either by self-report of the ability to speak two languages, or as speaking two languages for most of one's adult life. One study in this group also included an objective measure of language proficiency [26].

Five studies asked informants when they had first noticed participants' symptoms of cognitive impairment [7;10;11;27;28]. All of these studies found that bilingual participants' informants noticed symptom onset four to five years later than their monolingual counterparts. In all of these studies, bilingual participants were either more likely to be immigrants or to have had more years of education than monolingual participants.

Three studies used age of diagnosis at the clinic visit at which they were diagnosed with either all-cause dementia or MCI as the outcome [25;26;29]. Of these, two found no significant difference in age of diagnosis between monolinguals and bilinguals and no significant differences in years of education between the two groups [26;29]. The third study found that age of diagnosis of amnestic MCI, was on average 4·5 years later in bilinguals than monolinguals but there was no difference in age of diagnosis for multiple domain MCI (mean difference -2·6 years, $t(41)=1·11$; $p=0·27$) [25]. The monolingual and bilingual participants did not differ in years of education but there was no information on their employment or immigrant status.

Discussion

Our systematic review is the first to bring together all published evidence comparing cognitive decline or dementia in people who are bilingual compared to those who are monolingual. We found that, in individual prospective studies, there was no difference between bilingual and monolingual participants in the rate of development of dementia when baseline differences were taken into account. Combining these studies in this new meta-analysis has strengthened this conclusion as we found no reduction in the odds ratio of dementia in those who were bilingual compared to those who were not. By contrast, bilingual participants present around 4·5 years later in retrospective studies, where individuals' participation in the study depended on self-presentation, and time of initial symptoms are self-reported rather than standardised.

Studying the effect of an exposure, in this case bilingualism, on outcome is ideally carried out prospectively in order to reduce recall bias and clarify the temporal relationship. None of the prospective studies of the development of dementia as an outcome found any protective effect of bilingualism, either individually, when adjusted for confounders, or on meta-analysis. These studies were large, examined all participants for dementia using standard methods, with good follow-up rates, controlled for confounders, had a duration of 5-10 years and measured incidence of dementia, a clinically relevant outcome. As large high quality prospective studies have not shown an association between bilingualism and dementia, this indicates that bilingualism is not an independent protective factor.

A prospective but lower quality study (which did not control for sex or education) was not included in the meta-analysis as it measured cognitive function rather than

incident dementia. It found bilingualism had a protective effect on cognition. In this study, bilingual people scored more highly on the NART, which is a measure of premorbid attainment, suggesting higher cognition and education at entry; although there was no information on baseline differences in participants [22]. Thus differences in the groups' outcomes may be due to educational or social differences rather than to bilingualism itself.

Retrospective studies in this review usually used either informant report about the date of onset of symptoms or the date of presentation to memory clinic as date of onset. This is potentially influenced by many personal and cultural factors. People from minority ethnic backgrounds tend to seek help later for dementia [30] and may define the onset of symptoms differently, potentially explaining findings of later reported symptom onset from retrospective studies that included more immigrants in the bilingual group. Although some of these studies adjusted statistically for baseline differences in education, they cannot account for cultural differences in help-seeking.

Retrospective studies that did not include a greater number of people from immigrant backgrounds in the bilingual groups, usually included bilingual participants with higher levels of education. Education is protective against cognitive decline [31]. Although these studies have adjusted for education in their analyses, where group assignation is non-random, there is no way of determining whether associations between group membership (bilingual versus non-bilingual) and the dependent variable are due to random error or a true group difference [32]. In addition, years of education completed is not always an indicator of quality of education and the latter could be influenced by other variables such as socioeconomic status.

Two studies which did not qualify for inclusion, compared multilingual participants with bilingual participants. Both of these studies were conducted in countries where speaking multiple languages is common and participants were likely to switch between different languages many times a day. One study had a 14% follow-up rate and did not compare those who dropped out and those who did not [12]. The other was cross-sectional and found being multilingual rather than bilingual was protective, giving an odds ratio of 0·3 for cognitive impairment (95% Confidence Interval 0·10-0·92) after adjustment for education and age [13]. Both studies found that knowing and using more than two languages seems to confer a cognitive advantage and multi-lingualism may differ from bilingualism but there is not enough evidence as yet to draw definitive conclusions.

Strengths and limitations of this review

Our review was systematic and we searched using broad search terms and refined our search strategy to include as many potentially relevant papers as possible. We also hand searched references of relevant papers to identify further papers. We are therefore unlikely to have missed papers matching our inclusion criteria. We also emailed authors for missing information or clarification and this improved the accuracy of our information. Quality rating was completed using a scale which is widely used and independently derived. The quality was rated by two authors independently. However, only one author screened titles and abstracts for inclusion. We have not carried out a funnel plot to screen for publication bias but as most of the prospective studies found negative results, publication bias is unlikely to positively skew the results. We could only carry out a meta-analysis on unadjusted odds ratios so our estimate is likely to over-estimate the effect of bilingualism.

Conclusion

We did not find evidence that bilingualism, when appropriately adjusted for education, protects from cognitive decline or dementia. Public health policy should therefore remove recommendations regarding bilingualism [3] as a strategy to delay dementia and instead concentrate on more generally reducing cognitive inactivity [33].

Contributors: NM formulated the research question, did the literature search, extracted and selected articles, assessed article quality, did the primary analysis, and wrote the report. AS assessed article quality and wrote the report. GL formulated the research question, assessed article quality and wrote the report.

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Conflicts of interest: None.

Appendix

	Score
1. Cohort as representative of underlying population as possible.	**1**
2. Definition of bilingualism (one point for well-defined definition of bilingualism, another if objective measure of language ability).	**2**
3. Outcome measure is objective and valid. Ideally diagnosis should be made via structured assessment by trained people, valid scale or criteria for diagnosis.	**1**
4. Adjustment of results for confounders. One point for adjusting for age, sex, education and another point if took into account any of the following: immigration status/SES, vascular risk factor	**2**
5. At least 70% follow up rates	**1**
6. Length of follow up at least 5 years.	**1**
Total	**8**

Appendix Table 1: quality criteria

	Zahodne et al 2014	Sanders et al 2012	Bak et al 2014	Lawton et al 2015	Yeung et al 2014	Bialystok et al 2007	Bialystok et al 2014	Craik et al 2010	Ossher et al 2012	Chertkow et al 2010	Allaii et al 2013	Gollan et al 2011	Clare et al 2014	Woumans et al 2015
Was the cohort representative of a defined population?	1	1	1	1	1	0	0	0	0	0	0	0	0	0
Was the exposure (language status) accurately defined and measured?	2	0	1	1	1	1	1	1	1	1	1	2	2	1
Was outcome clearly defined and measured?	1	1	1	1	1	0	0	0	1	1	0	1	1	0
Have the authors identified and controlled for all	2	2	0	0	1	1	2	1	0	2	2	0	0	1

important confounding factors?														
Was follow-up complete enough (>70%)?	0	1	1	1	1	0	0	0	0	0	0	0	0	0
Was follow-up long enough (>5 years)?	1	1	1	1	1	0	0	0	0	0	0	0	0	0
Total(8)	7	6	5	5	6	2	3	2	2	4	3	3	3	2

Appendix Table 2: Quality scores

Reference List

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Ref Type: Report

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Ref Type: Journal

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Ref Type: Report

Figure 1: PRISMA diagram showing search results and included studies

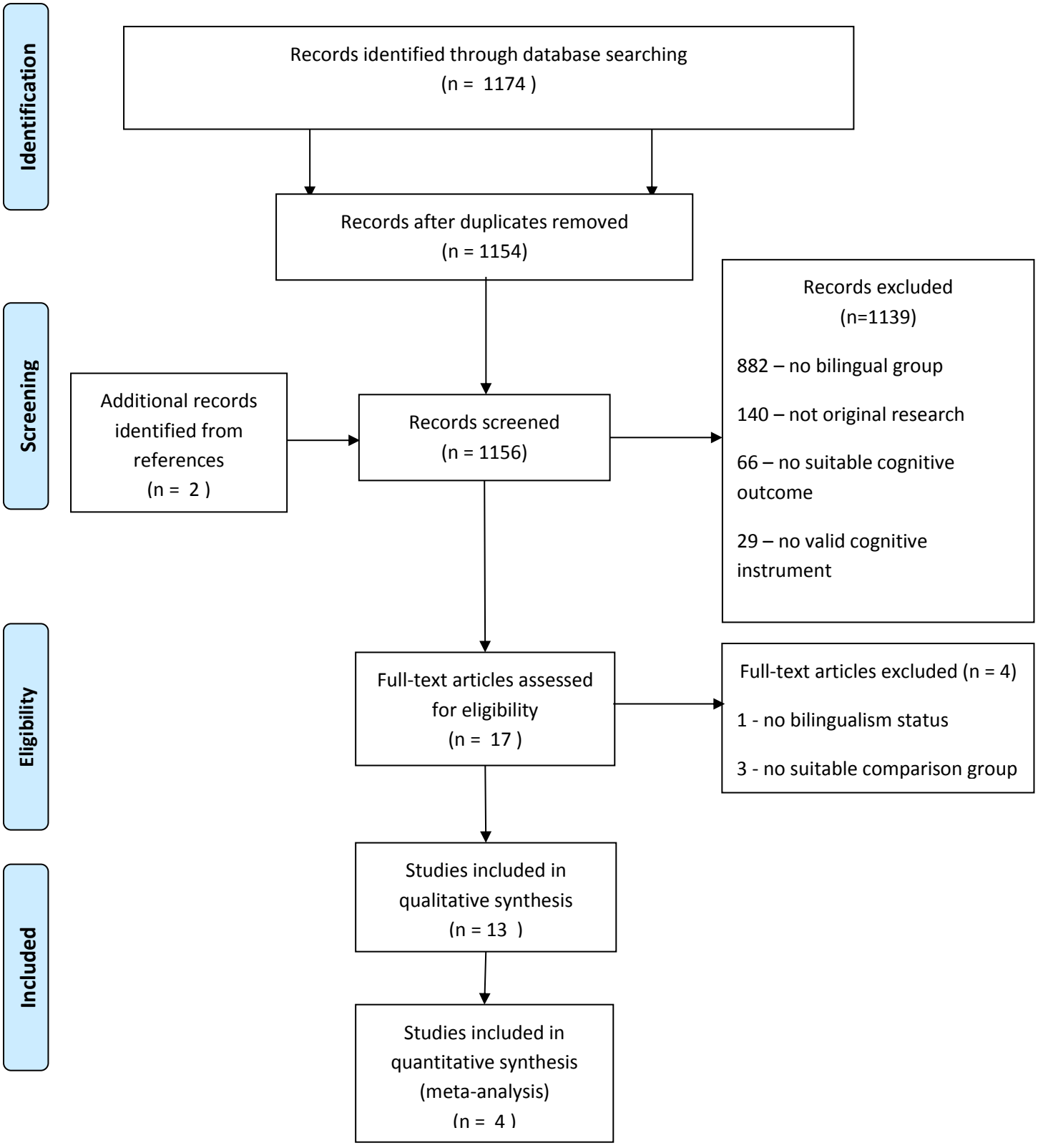
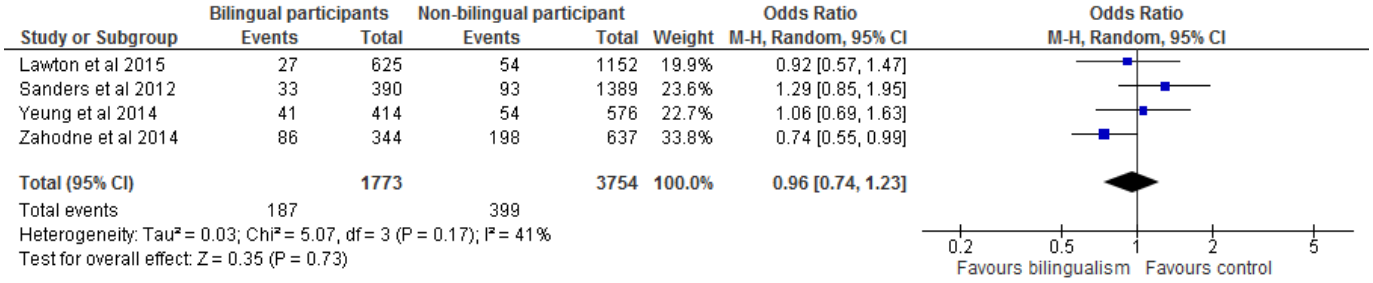


Figure 2: Forest plot showing odds ratio of developing dementia in those defined as bilingual versus those who were not



Study	Quality score	Participants and Setting; Country	N	Number of years follow-up	Follow-up rate (%)	Definition of bilingualism; comparator groups	Procedure	Baseline differences	What controlled for	Outcome
Bak et al 2014	5	Healthy general population of people aged 11 years in 1947 – from Scottish Mental Survey; Scotland	853	50	78.1	Bilingualism self-defined as learning another language well enough to communicate in it; monolingual	Childhood intelligence (CI) at age 11 then cognitive tests 50 years later	Not stated	CI, age, sex, participant and father's social class	Passive/active bilingualism ↑ scores on g-factor (estimate 0.23/0.29, p=0.01/0.03)
Lawton et al 2015	5	Community dwelling Hispanic people identified from census; USA	1789	10	99.3	Bilingualism self-defined as speaking more than one language at least "very often"; monolingual	Cognitive screen. If scores low further neuropsychology testing and specialist adjudication	Bilingual participants had significantly more years education	Immigrant status	Mean age of dementia diagnosis of bilingual participants (79.31 years) not significantly different from monolingual participants (81.10), F (1, 77) = 1.27, p = 0.26

Sanders et al 2012	7	Community based longitudinal study of aging. Medicare recipients or registered voters sampled; USA	1779	7	91.6	Non-native English speakers (NNES) (bilingual); native monolingual English speakers (NES)	Neuro-psychological assessment at baseline; then annually. Dementia diagnosis by specialist consensus	NNES older, more likely to be white, married and immigrant, less educated, less hypertension than NES	Sex, race, years of education, immigration marital status, self-reported hypertension, diabetes, myocardial infarction, and stroke	No association between NNES status and incident dementia (HR 1.26, 95% CI 0.76-2.09; p=0.36).
Yeung et al 2014	5	Longitudinal study of Community dwelling elders, randomly selected from health care register ; Canada	1468	5	67.4	Self-described: Monolinguals (56%) vs English as second language (38%) vs English bilinguals (5%)	Cognitive screening. Specialist examination & diagnosis if scored below cut off	No significant differences in age or education across all groups.	Age, sex, education, subjective memory loss at baseline	No association between language status and dementia: Adjusted OR 0.99 (95% CI 0.61, 1.59) in bilinguals versus monolinguals
Zahodne et al 2014	7	Longitudinal aging study, from Medicare registry.	1067	23	80.8	All Spanish speakers. Bilinguals reported speaking English	Cognitive tests administered at each visit.	Bilinguals younger, more education,	Age, sex, education, proportion of life spent in the U.S.,	No difference in adjusted rate of dementia conversion in Cox

		No baseline cognitive impairment; USA				'well' or 'very well'. Subgroup validated with reading test	Diagnosis by specialist consensus	more females, younger age of immigration	country of origin, and recruitment wave	regression: HR=1.18 (95% CI: 0.96 - 1.46)

Table 1: Prospective studies. *MHT = Moray House Test (verbal reasoning)

Study	Quality score	Setting and participants; Country	N	Definition of bilingualism; comparator group	Procedure	Baseline differences	What controlled for	Outcome
Alladi et al 2013	3	People in memory clinic diagnosed with dementia; India	648	Self-defined ability to communicate in more than one language; monolinguals	Family members of people with dementia asked when first symptoms noticed	Bilinguals more likely to be male, have received more education, be urban dwellers	Literacy, years of education, sex, family history, vascular risk	Bilinguals onset of symptoms 4.5 years later than monolinguals unadjusted $p<0.0001$ Adjusted analyses $F_{1458} = 4.89$, $p=0.027$
Bialystok et al 2007	2	People in memory clinic diagnosed with dementia; Canada	184	Most of adult life using two languages, judged by specialists based on notes; monolinguals	People with dementia and their family members asked when first symptoms noticed	Bilinguals older, less educated, lower MMSE, lower occupation, more likely to be immigrants	Age, education and occupation	Bilinguals onset of symptoms 4 years later than monolinguals, $p<0.003$, No difference in rate of cognitive decline.
Bialystok et al 2014	3	People in memory clinic diagnosed with dementia or MCI & no other neurological condition; Canada	149	Majority of adult life using two languages, judged by specialists; monolinguals	Patients and family members of people asked when first symptoms noticed	Bilinguals significantly less educated, more likely to be migrants, less likely to smoke and drink alcohol.	Education and immigration	Bilinguals onset of MCI symptoms 4.7 years than monolinguals and 7.2 years later Alzheimer's dementia $F_{1,145}=10.75$, $p=0.001$.

Chertkow et al 2010	4	Memory clinic patients diagnosed with dementia; Canada	632	Most of adult life using two or more languages; monolinguals	Clinician consensus about age at dementia diagnosis.	No between group differences in age, years of education or initial MMSE.	Sex, education and immigrant status	No significant difference between bilingual and monolinguals' age of diagnosis or MMSE scores.
Clare et al 2014	3	Memory clinic patients or on register diagnosed with dementia and MMSE score >18/30; Wales	86	Self-defined, speaking >1 language for most of life. Also objective measure of proficiency; monolinguals	Age at time of diagnosis from clinical records.	Bilinguals less highly qualified though years education not significantly different	Education	No significant difference in age of diagnosis $F(1,79)=2.97$, $p=0.089$) or executive function scores
Craik et al 2010	2	People in memory clinic diagnosed with dementia ; Canada	211	Majority of adult life using two languages, judged by specialists based on notes; monolinguals	Patients and family members of people asked when first symptoms noticed	Bilinguals older, less educated, more immigrants, lower employment status	Sex	Bilinguals onset of symptoms 5.1 years than monolinguals. Two way ANOVA ($F(1205)=16.25$, $p<0.0001$) with bilingualism and sex.
Ossher et al 2012	2	People referred by physician or advert responders with	111	Majority of adult life using two languages, judged by specialists	Screened by memory tests. Those with objective memory	No significant differences in education or gender. No	Nil	Bilinguals onset of amnestic MCI 4.5 years later than monolinguals ($t(66)=2.46$, $p<0.02$). No

		subjective memory complaints and at least MCI on testing; Canada		based on info in notes; monolinguals	impairment had more f cognitive tests for MCI subtype.	information on employment status		difference in multiple domain MCI or in duration of symptoms based on informant report.
Woumans et al 2015	2	Memory clinic patients with dementia diagnosis; Belgium	134	Self-defined at least "good" on second language and speaking it ≥ once a week; monolinguals	Family members of people diagnosed with dementia asked when first symptoms noticed	No statistics given but bilinguals more educated	Sex, occupation and education	Age of onset of symptoms 4.6 years later in bilinguals (F(1109)=7.05, p=0.009)

Table 2: Retrospective studies