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Bilingualism and delayed clinical manifestation of Alzheimer's disease: A systematic review

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ABSTRACT

Objective: *Motivated by the Cognitive Reserve (CR) theory, this systematic review examines the relation between bilingualism and the onset of Alzheimer's disease (AD).*
Method: Guided by PRISMA, this review identified and evaluated empirical studies comparing bilingual and monolingual adults on age at symptom onset or diagnosis of MCI and AD. Searches were conducted in Web of Science and PubMed using predefined keywords linked to bilingualism, AD, and cognitive reserve. Inclusion criteria required primary comparative studies that applied validated diagnostic criteria, used standardized cognitive measures, and reported age of onset or diagnosis for both groups. Data were extracted on study design, participant characteristics, diagnostic criteria, and age at onset.
Results: *Across studies, several findings suggest that bilingual individuals may experience a later onset of cognitive symptoms relative to monolingual peers. Reported delays range from approximately 3.2 to 7.2 years for the emergence of clinical complaints associated with MCI and AD. In line with the CR hypothesis, lifelong bilingual language use may strengthen neural efficiency and resilience, delaying clinical decline. Nonetheless, findings should be interpreted cautiously given mixed results, methodological variability, heterogeneous definitions of bilingualism, and potential publication bias.*
Conclusion: *Findings from several retrospective observational studies suggest that bilingualism may be associated with delayed clinical manifestation of AD symptoms in some populations. This finding has important implications for cognitive health and may open up new research and treatment options.*

Keywords:

Cognitive reserve, Alzheimer's disease, Mild Cognitive Impairment, Dementia, Bilingualism

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INTRODUCTION

The world population is aging, and this fact will greatly impact health systems and the people who take care of elders. As a result, during the last decade, there has been an increase in the number of people suffering from neurocognitive disorders[1], including dementia. Alzheimer's disease (AD) is the most common cause of dementia, affecting between 60 and 70% of dementia cases[2]. It is a chronic, progressive and neurodegenerative disorder[3] characterized by a progressive loss of episodic memory, visuospatial and linguistic skills, the ability to form concepts, psychomotor speed, and neuropsychiatric symptoms[4-5].

Currently, the most widely recognized theory to explain the emergence of AD neuropathology is the amyloid hypothesis[6]. The criteria for AD diagnosis have been revised extensively, and experts agree that this disorder has two distinctive peptidic hallmarks: extracellular deposition of amyloid-beta (Aβ) plaques and hyperphosphorylated tau[7-8], which interfere with the mitochondrial functioning of the neuron[8]. Tau is a microtubule assembly protein that accumulates intracellularly as neurofibrillary tangles[7,9]. Some neurofibrillary tangles also get incorporated into the amyloid plaques[10]. The entorhinal and perirhinal cortices are the first sections of the cortex impacted by tangles, with the hippocampus being relatively spared, and then spread to the association cortices of the frontal, temporal, and parietal lobes over time[9,10]. Both hallmarks are hypothesized to damage brain structures, impair brain metabolism, and result in the clinical manifestation of the disease[11].

The most important known risk factors for AD are age, genetics, and family history. Of these, age has the greatest impact on risk[3,12,13]. The probability of having AD increases with age, with incidence rates doubling every five years from age 65 to at least age 90[14]. Currently, an estimated 47 million people worldwide are living with the disease[3,5], and this number is expected to increase to more than 115 million by 2050[2,14-19].

With these numbers on the rise, the amount of research on protective factors and cognitive reserve (CR) that can delay the onset of dementia symptoms is of great importance. It is estimated that a five-year delay in the onset of the disease could reduce the number of patients worldwide by 57%, alleviating the associated economic costs of treatment and caregiving[16].

CR refers to how individuals actively use neural resources to cope with neuropathology in order to maintain cognitive functioning[13,18,20]. CR is characterized by the individual ability to enhance neural networks and maintain cognitive function despite neural changes associated with age[21]. Several variables, including overall cognitive capacity, education, occupation, physical activity, and bilingualism, have an impact on CR[13,22-23].

Klein et al.[24] refer to the idea that certain daily activities can provide some protection against attacks on the central nervous system. Activities such as playing instruments, video games, or being bilingual can provide a protective factor. Several studies hypothesize that bilingualism, as a result of better CR, is associated with improved executive function and may delay the onset of dementia, especially AD[25-26]. Bilingualism is commonly defined as the use of two languages: a native language (L1) and a second language (L2). It might also be characterized by early L2 acquisition, strong L2 proficiency, and frequent language switching[13,27-28].

In a pioneering study from 2007, Bialystok et al.[29] reported that bilingual patients with probable AD were diagnosed about four years later than monolingual patients. Since then, researchers and most retrospective studies around the world have suggested that bilinguals develop mild cognitive impairment, dementia, and AD about 4 to 7 years later than monolinguals[1,16,30-31].

There are methodological limitations in research on the protective effect of bilingualism against cognitive decline and major neurocognitive disorders. Evidence for a protective effect has been found, but results are mixed. Several factors, such as immigration and individual experiences, appear to influence the extent of the

CR-enhancing effect of lifelong bilingualism[1]. Still, an increasing body of evidence suggests that bilingualism is associated with greater CR and a potentially later onset of AD symptoms, allowing affected individuals to live independently for longer than monolingual people[20]. For example, Woumans and collaborators[19] reported a significant delay for bilinguals of 4.6 years in symptom manifestation and 4.8 years in diagnosis, reinforcing the claim that bilingualism contributes to CR and postpones dementia symptoms. However, some studies remain controversial due to mixed findings. These inconsistencies stem from combining dementia incidence rates with the age at which symptoms first appear, as well as from methodological flaws in study designs.

Given recent evidence suggesting an association between bilingualism and reduced age-related cognitive decline, it is crucial to better understand how it influences neuroplasticity. Therefore, this review aims to provide a comprehensive systematic analysis of the existing literature on bilingualism and AD, focusing on age of onset, incidence rates, and evidence from both retrospective and prospective studies. In doing so, it assesses the effects of bilingualism compared to monolingualism on the clinical manifestation of AD, based on the hypothesis that bilingualism may not be a direct protective factor but may be associated with a delayed onset of clinical symptoms.

The central question is: When considered as a source of accumulating cognitive and brain reserves, what role does bilingualism play in delaying the onset of symptoms in a neurodegenerative disease like AD?

METHOD

Design

In research, evidence-based decision making requires rigorous examination of existing literature. For this reason, we chose a systematic review design, which aims to comprehensively summarize and critically evaluate prior evidence on a specific research question[32-33]. The review process involves developing a research question, identifying databases, conducting a comprehensive search, screening studies, assessing quality, extracting relevant data, and synthesizing the findings[33].

Instruments

We used the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) checklist[34], a standardized tool widely endorsed by organizations such as the Cochrane and Campbell Collaborations. The checklist contains 27 items covering methodology, results, and interpretation, including eligibility criteria, research questions, quality assessment, search strategies, study characteristics, and data synthesis[32,34].

Procedure and Data Analysis

Our guiding research question was: "When considered from the perspective of bilingualism as a source of accumulating cognitive and brain reserves, what is the role of bilingualism in the potential delay of the symptom onset for a neurodegenerative disease like AD?". Searches were conducted in Web of Science and PubMed using the terms: *"AD onset bilingualism"*, *"AD bilingualism"*, *"Alzheimer's bilinguals"*, *"cognitive reserve in AD"*, and *"dementia bilingualism"*. Filters included article types such as 'Comparative Study', 'Meta-Analysis', 'Multicenter Study', 'Observational Study', and 'Clinical Trials'. Additional backward searches (reference lists) were also performed and applied identically across databases. Records were obtained from 2002 to the end of July 2023, with the final search date being July 30th, 2023.

Only PubMed and Web of Science were searched as these databases provide a broad coverage of neuropsychological and interdisciplinary aging research relevant to bilingualism and AD. However, the omission of additional databases may have limited the comprehensiveness of the search and is acknowledged as a limitation.

Inclusion criteria required studies to: (a) address AD or amnestic MCI; (b) be primary research examining bilingualism and AD; (c) compare bilingual and monolingual groups; (d) report validated

cognitive outcomes, incident dementia, or MCI; (e) report mean age of onset or incidence for both groups; and (f) diagnose AD based on NIA-AA, NINCDS-ADRDA, or DSM criteria. Exclusion criteria eliminated studies not in English, not peer-reviewed, not empirical (e.g., reviews), or those comparing multilinguals and bilinguals without a monolingual group.

Cohort, cross-sectional, and case–control studies were included, while editorials, case reports, case series, and narrative reviews were excluded. Outcomes of interest included age at diagnosis, time of clinical manifestation, and incidence. Studies of mixed dementias were considered only if AD data were reported separately. Studies using validated cognitive and neuropsychological measures (e.g., MMSE, MoCA, CDR, Stroop, TMT, BNT, FCSRT, RAVLT, CVLT, ROCF, WAIS, WMS-R, DRS, D-KEFS, Bilingual Aphasia Test, and language questionnaires) were included.

Because the included studies examined a range of related but distinct clinical outcomes, there was substantial conceptual heterogeneity across studies. These outcomes may reflect different stages of disease progression, healthcare access, diagnostic practices, or methodological approaches. For example, age at symptom onset often relies on retrospective patient or informant report and may be influenced by recall bias, whereas age at diagnosis may be affected by healthcare access, sociocultural factors, and/or clinician judgment. Similarly, incident dementia and aMCI outcomes reflect longitudinal risk and disease conversion processes that differ conceptually from cross-sectional estimates

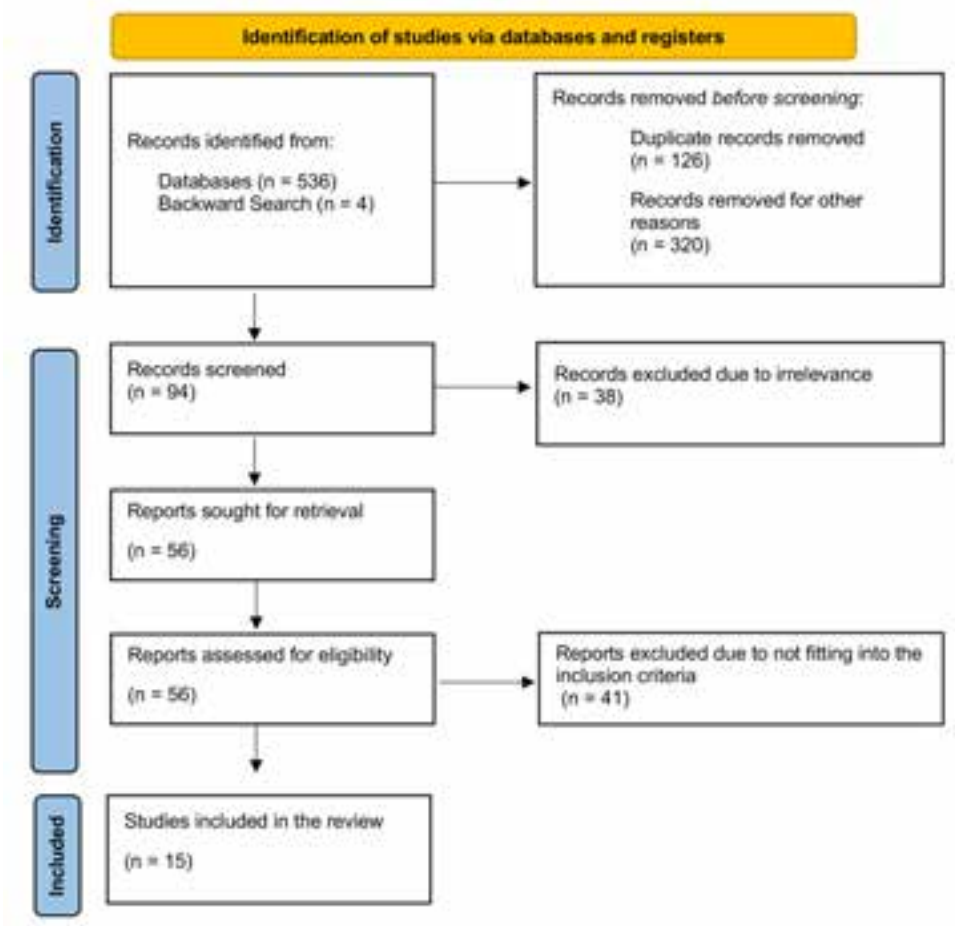

Figure 1. PRISMA Diagram

of symptom emergence. Consequently, findings across studies were interpreted cautiously, with recognition that variation in outcome definitions and measurement approaches may contribute to inconsistencies in reported associations between bilingualism and AD-related outcomes.

Titles, abstracts, and full-text articles were screened by three reviewers. Screening was conducted independently, and disagreements were resolved through discussion. Data extracted from included studies included study design, sample size, participant characteristics, diagnostic criteria, cognitive measures, neuroimaging methods, and definitions of bilingualism. A summary table was created with two sections: diagnosis (clinical criteria, sample sizes, bilingual vs. monolingual onset ages, measures, methods) and results (evidence coded as "positive," "negative," or "partial" regarding delays in symptom onset, with conclusions).

A formal methodological quality assessment or risk-of-bias evaluation was not conducted. As a result, the strength and quality of evidence across included studies should be interpreted cautiously, and this represents an important limitation of the review.

RESULTS

The initial search across PubMed and Web of Science yielded 536 articles. A supplementary backward search added four relevant articles identified through reference lists. After removing 126 duplicates and excluding 320 articles that did not meet the predefined search criteria, 56 articles remained for full eligibility screening. Of these, 41 were excluded for reasons such as absence of bilingualism or second language acquisition, non-empirical study design, or comparisons without a monolingual control group. Ultimately, 15 studies met all inclusion criteria and were selected for comprehensive analysis.

Table 1. Background information for studies included in the systematic review

Diagnosis							Results		
Study	**Objective**	**Clinical Criteria**	**Number of subjects (Bilingual/ Monolingual)**	**Age of onset (B/M)**	**Neuro imaging techniques**	**Cognitive measures**	**Bilingualism**	**Evidence**	**Conclusions**
Craik et al., 2010	To present evidence that lifelong bilingualism contributes to cognitive reserve	NINCDS-ADRDA	211 B = 102 M = 109	B = 77.7 M = 72.6	None reported	MMSE	The criteria for being classified as bilingual was having spent a significant portion of life, at least since early adulthood, routinely using at least two languages. 21 different languages were documented in this sample.	Positive	It was discovered that bilingual patients were diagnosed 4.3 years later and reported the onset of symptoms 5.1 years later than monolingual individuals.

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Mendez et al., 2019	Aimed to examine the effects of bilingualism on the emergence of AD symptoms in 253 patients with probable AD over a 15-year period	NIA-AA	253 B = 74 M = 179	B = 62.4 M = 58.0	Magnetic resonance imaging (MRI); fluorodeoxy-glucose positron emission tomography (FDG-PET)	MMSE; Neuro-behavioral Status Examination (NBSE); digit span forward and backward; numbers of "F" words/minute and category (animals)/ minute; 15-item mini-Boston Naming Test (mBNT); 10-item (5 registration trials) verbal learning test with 15-min delayed recall and 20-item recognition.	Language use in the first 5 years of life, later acquisition of English, immigrant status, historical ability to use both languages daily, whether English was the predomi-nant language at work or outside the home, and any change in current language use. 15 different languages were documen-ted in this sample.	Positive	Bilinguals had roughly 4-year delays in the ages of onset and presentation. The study also discovered frequent regression to the first language learnt or native tongue. This means that bilingualism appears to disguise cognitive deterioration by making a first language or "L1" available as a "back-up" language.
Ramakrishnan et al., 2017	Aimed to assess how education and bilingualism influence the onset of cognitive decline during the MCI stage.	Petersen's criteria	115 B = 93 M = 22	B = 63.2 M = 55.8	Patients were evaluated by brain imaging to exclude other causes of MCI.	Addenbrooke's Cognitive Examination-Revised (ACE-R) or its later version Addenbrooke's Cognitive Examination-III (ACE-III); Clinical Dementia Rating (CDR) Scale; Rey Auditory Verbal Learning Test-Delayed Recall (RAVLT-DR); TMT-B; Color Trails Test-B (CTT-B)	Language was assessed on a 26-point composite scale derived from the ACE-R and ACE-III. Languages were not specified.	Positive	This study found that bilingual MCI patients were found to have a clinical onset of cognitive complaints 7.4 years later than monolinguals (65.2 vs. 58.1 years) while years of education was not associated with delayed onset.

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Zheng et al., 2018	To establish whether being bilingual in Cantonese and Mandarin can delay the onset of AD	NINCDS-ADRDA	129 B = 61 M = 68	B = 74.4 M (Cantonese) = 67.7 M (Mandarin) = 67.0	None reported	MMSE	Bilinguals were defined as individuals who, starting in early adulthood, fluently spoke two languages for most of their lives, preferably daily but at least weekly. Languages docu-mented were Cantonese and Mandarin.	Positive	Cantonese/ Mandarin bilingual AD patients were significantly older at AD symptoms onset (70.93 years) than Cantonese (n = 63.90) and Mandarin monolinguals (n = 63.40)
de Leon et al., 2020	Examined the difference in dementia onset age between bilinguals and monolinguals in 287 people with amnestic Alzheimer's disease or logopenic variant primary progressive aphasia (lvPPA).	NIA-AA	287 AD B = 28 AD M = 179	B = 60.9 M = 60.9	None reported	CDR; MMSE	Bilingual patients were those whose records showed they routinely used two or more languages and/or could communi-cate with native speakers in two or more languages. Languages were not specified.	Negative	The impact of clinical diagnosis and bilingualism on age of symptom onset was examined using analyses of covariance (ANCOVAs). In lvPPA patients, bilingualism was linked to a considerable delay in the onset of dementia. This difference was not observed in Amnestic AD.

Table 1. Background information for studies included in the systematic review

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Berkes et al., 2020	Aimed to examine the rates of MCI to AD while using bilingualism as a proxy for cognitive reserve	Criteria not reported	158 B = 75 M = 83	B = 77.8 M = 75.5	CT, SPECT, MRI	Mini-Mental State Examination (MMSE); Montreal Cognitive Assessment (MoCA). Kaplan-Baycrest Neuro-cognitive Assessment; Wechsler Memory Scale-Revised (Logical Memory); Wechsler Abbreviated Scale of Intelligence; Wechsler Adult Intelligence Scale −3; Delis-Kaplan Executive Function System; Trail Making Test; Verbal Fluency; Boston Naming test	The key factors of bilingualism were knowledge of more than one language, regular use of a language other than English, and residence in a non-English speaking nation. 23 different languages were documented in this sample.	Positive	MCI was detected in bilingual participants at a later age (77.8 years) than in monolingual individuals (75.5 years). However, bilinguals shifted from MCI to AD faster than monolinguals (1.9 and 2.6 years, respectively), a significant difference.
Chertkow et al., 2010	To assess the age at the time of their AD diagnosis and the age at AD symptom onset	NINCDS-ADRDA	547 B = 168 M = 379	Multi = 72.5 M = 71.5	None reported	Structured interview; MMSE	Bilinguals were defined as those who spoke both French and English from youth. Monolinguals spoke either only French or only English.	Partial	Multilingualism showed a minor protective effect, while bilingualism had no impact on age at diagnosis or symptom onset compared to monolinguals.

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Study	**Objective**	**Clinical Criteria**	**Number of subjects (Bilingual/ Monolingual)**	**Age of onset (B/M)**	**Neuro imaging techniques**	**Cognitive measures**	**Bilingualism**	**Evidence**	**Conclusions**
Bialystok et al., 2007	To study lifelong bilingualism's impact on cognitive function and dementia symptom onset in old age	NINCDS-ADRDA	184 B = 93 M = 91	B = 75.5 M = 71.4	None reported	Clinical examination; MMSE; and interviews	Bilingual individuals were character-ized as those who, starting in their early adulthood, had been proficient in speaking at least two or more languages, ideally daily, but at least weekly. 25 different languages were docu-mented in this sample.	Positive	The results indicate that bilingual individuals may experience dementia symptoms approxi-mately four years later than monolinguals, with no apparent impact on the progression of the condition.
Bialystok et al., 2014	To examine the association between bilingualism and the onset age of dementia's cognitive symptoms and the rate at which these symptoms deteriorate in both monolingual and bilingual dementia patients.	Consensus diagnosis by two physicians and a neuropsy-chologist	149 (MCI = 74; AD = 75) B MCI = 36 M MCI = 38 B AD = 40 M AD= 35	B AD = 78.2 M AD = 70.9 B MCI = 66.9 M MCI = 62.2	None reported	Language and Social Background Questionnaire (LSBQ); lifestyle questionnaire; Onset of symptoms interview; Delis-Kaplan Executive Function System Tests (D-KEFS)	Bilingual individuals were character-ized as those who, starting in their early adulthood, had been proficient in speaking at least two or more languages, ideally daily, but at least weekly. Languages were not specified.	Positive	Significant delay in the onset of cognitive symptoms in patients with MCI and AD (3.2 and 7.2 years, respectively).

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Ossher et al., 2013	To examine the effect of bilingualism on aMCI	Clinical evaluation by two neuropsy-chologists was used to diagnose participants into single-domain or multiple-domain aMCI groups	111 Single-domain aMCI B = 19 M = 49 Multiple-domain aMCI B = 21 M = 22	B = 79.4 M = 74.9	None reported	MMSE; administered two subtests from the D-KEFS battery of executive function tests (Color-Word Naming and Verbal Fluency classification as single- or multiple-domain aMCI was based on performance on Digit Span (Wechsler, 1997), Boston Naming Test, Rey-Osterreith Complex Figure Copy, and Trail Making Test	Majority of adult life using two languages. Languages were not specified.	Partial	Bilinguals with single-domain aMCI were diagnosed, on average, 4.5 years later than monolin-guals, but this advantage was not evident in the multiple-domain aMCI group. Only those with single-domain aMCI showed a delayed diagnosis among bilinguals, with no difference observed in multiple-domain aMCI cases.
Alladi et al., 2013	To examine how bilingualism relates to dementia onset age and its subtypes, while considering potential influencing factors.	Criteria not reported	240 B = 142 M = 98	B = 68.6 M = 65.4	None reported	MMSE, Addenbrooke's Cognitive Examination–revised (ACE-R), Clinical Dementia Rating (CDR)	Bilinguals in this study were identified according to Mohanty's definition, which involves meeting the communi-cative demands of self and society in two or more languages during interactions with other speakers of those languages. Four different languages were docu-mented in this sample.	Positive	Delay of 3.2 years in the onset of AD symptoms in bilinguals compared to monolinguals.

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Study	**Objective**	**Clinical Criteria**	**Number of subjects (Bilingual/ Monolingual)**	**Age of onset (B/M)**	**Neuro imaging techniques**	**Cognitive measures**	**Bilingualism**	**Evidence**	**Conclusions**
Woumans et al., 2014	To investigate how bilingualism affects the clinical presentation of AD	Criteria not reported	134 B = 65 M = 69	B = 76.1 M = 71.5	None reported	Clinical examination, MMSE, screening blood tests, neuro-imaging, and self-reports	Bilingualism was established by evaluating L2 proficiency and usage frequency on a scale from perfect/ native to nonexistent and used this language at least weekly. Four different languages were documented in this sample.	Positive	The findings reveal a significant postponement of 4.6 years in the onset and 4.8 years in the identification of symptoms for bilingual individuals.
Clare et al., 2014	Compare age at AD diagnosis and performance on a range of executive control tasks in bilinguals and monolinguals	ICD-10	86 B = 37 M = 49	B = 79.27 M = 76.23	None reported	MMSE; EQ-5D visual analogue scale; Hospital Anxiety and Depression Scale; Lifetime of Experiences Questionnaire, Dementia Rating Scale-2; Raven's Colored Progressive Matrices; Physical Self-Maintenance; Instrumental Activities of Daily Living scales; Functional Activities Questionnaire; D-KEFS	A language question-naire was used to evaluate language to determine the language(s) spoken, level of skill, and past and present language use. National Adult Reading Test-Revised, Boston Naming Test, Spot-the-Word Test, and British Picture Vocabulary Scale. Bilinguals were defined as those who spoke Welsh and English.	Partial	No significant group differences in executive function test performance or age at diagnosis were observed. Despite a significant three-year age difference at diagnosis, bilinguals exhibited significantly more cognitive impairment upon diagnosis.

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Yeung et al., 2014	The objective of this study was to investigate the potential link between bilingualism and dementia in older adults through cross-sectional and prospective analyses.	Dementia was determined by clinical examination	1,616 M = 913 English B = 81 ESL = 622	Study did not have specific age of onset information.	No neuroimaging information provided	MMSE	Language status was categorized based upon self-report into 3 groups: English as a first language (mono-lingual English, bilingual English) and English as a Second Language (ESL). Other languages were not specified.	Negative	No association between speaking more than one language and dementia.
Zahodne et al., 2014	To examine the hypothesis that bilinguals receive a dementia diagnosis at an older age compared to monolin-guals	DSM-III	1,067 B = 430 M = 637	Study did not have specific age of onset information.	None reported	Selective Reminding Test; BNT; tests of verbal and nonverbal abstraction and letter fluency; Color Trails Test; Cox regression	All participants listed Spanish as their first language. Bilinguals were defined as those who indicated they spoke English not well, well, or very well.	Negative	The findings do not support a protective effect of bilingualism on age-related cognitive decline or the develop-ment of dementia

Across the included studies, findings generally suggested an association between bilingualism and later onset of AD-related clinical symptoms; however, results were heterogeneous and not uniformly consistent. Several studies reported delayed age at symptom onset or diagnosis among bilingual individuals relative to monolingual peers, with estimated delays commonly ranging from approximately 3 to 7 years. In one study[35], bilingual patients were diagnosed approximately 4.3 years later and reported the onset of symptoms 5.1 years later compared to their monolingual counterparts. This temporal cushioning suggests that bilingualism may act as a protective factor, offering a substantial respite in the early stages of cognitive decline. This trend was evident in several other studies that reported comparable delays of roughly 4 years in the age of symptom onset and presentation for bilingual individuals. Collectively, these findings point to the possibility that bilingualism could play a pivotal role in disguising cognitive deterioration and extending the CR of individuals, despite ongoing neuropathology. Bilingualism continued to exhibit its protective potential as Cantonese/Mandarin bilingual AD patients were found to experience a significantly later onset of AD symptoms, roughly around 7 years later compared to Cantonese and Mandarin monolinguals.

In studies regarding MCI, the findings remained robust, with bilingual MCI patients experiencing clinical onset of cognitive complaints a remarkable 7.4 years later than monolinguals. Such delays in MCI diagnosis are particularly crucial since MCI often precedes more severe cognitive disorders like AD. Additionally, some studies observed that bilingual individuals with single-domain amnestic MCI were diagnosed approximately 4.5 years later than their monolingual peers, although this advantage was not uniformly evident in cases of multiple-domain amnestic MCI.

Moreover, some studies suggested that the delay in AD symptom onset among bilinguals was around 3.2 years compared to monolinguals. However, it is essential to note that despite the postponement in symptom onset, the progression of the condition did not appear to be significantly affected by bilingualism, as observed in multiple studies. Overall, these findings may suggest a potential temporal advantage in the onset of cognitive symptoms for bilingual individuals, highlighting a noteworthy relationship between bilingualism and cognitive decline.

In contrast, three studies emphasized that bilingualism did not necessarily offer a protective effect against age-related cognitive decline or the development of dementia. Despite the consistent delays in symptom onset and diagnosis, some research did not detect significant group differences in executive function test performance or age at diagnosis between bilingual and monolingual individuals, underscoring the complexity of this relationship. Two studies even failed to establish a clear connection between speaking more than one language and dementia, implying that any potential influence of bilingualism on cognitive aging may be multifaceted and context dependent. Although one study demonstrated a minor protective effect in the case of multilingualism[39], the three other studies mentioned above did not support the notion of bilingualism as a protection against age-related cognitive decline due to the disease[38,44-45].

Given the substantial heterogeneity across included studies, a formal meta-analysis was not conducted. Studies differed considerably in design, participant characteristics, outcome definitions, and operationalization of bilingualism, limiting the feasibility and interpretability of pooled quantitative estimates. Specifically, studies variably defined outcomes as age at symptom onset, age at diagnosis, MCI onset, time to clinical manifestation, or dementia incidence, which represent related but distinct clinical constructs. Additionally, definitions of bilingualism differed substantially across studies and included differences in language proficiency, age of acquisition, frequency of use, immigration status, multilingualism, and self-reported versus objectively measured bilingual experience. This variability limited direct comparability between studies and complicates interpretation of overall effect estimates. Consequently, findings were synthesized narratively rather than quantitatively.

To facilitate descriptive synthesis, studies were broadly categorized according to whether findings supported positive (associations were found), negative (associations were not found), or partial (some associations were found) associations between bilingualism and delayed AD-related outcomes. However, these categories were intended only as descriptive summaries and should not be interpreted as definitive indicators of study quality or strength of evidence. Because these classifications involved some degree of subjective interpretation, they represent an additional limitation of the review.

Several potentially important confounding variables were also inconsistently addressed across studies, including immigration history, education quality, socioeconomic status, occupational complexity, literacy, healthcare access, and cultural background. These factors are particularly relevant in bilingualism research because they may independently contribute to cognitive reserve and influence dementia risk, diagnosis, or symptom reporting. Variability in the extent to which studies measured or controlled for these variables further limits comparability across findings and should be considered when interpreting the observed associations between bilingualism and AD-related outcomes.

DISCUSSION

The findings suggest that bilingualism may act as a protective factor, offering a substantial buffer in the early stages of cognitive decline[19,29,35]. Across multiple studies, bilingual individuals consistently experienced significant delays in symptom onset compared to monolinguals, ranging from 3.2 years[12,42,] to 4 years[29,31,19], 5 years[35], and up to 7.2 years[36-37,40.] These findings highlight the potential role of cognitive reserve (CR) in delaying dementia symptoms. However, delayed symptom onset and diagnosis may also reflect factors beyond bilingualism itself, including differences in healthcare access, cultural perceptions of cognitive decline, immigration-related barriers, underreporting of symptoms, or reduced sensitivity of cognitive assessments in culturally and linguistically diverse populations. Additionally, bilingual individuals may compensate more effectively during cognitive testing, potentially masking impairment and delaying clinical recognition rather than altering underlying neuropathology. Consequently, later diagnosis should not necessarily be interpreted as evidence of slower disease progression or reduced disease burden.

One striking example comes from Zheng et al.[37], who found that Cantonese/Mandarin bilingual patients were nearly 7 years older than monolinguals at symptom onset. Their results raise the possibility that tonal, character-based languages may impose greater cognitive demands than alphabetic languages like English or Spanish, which could partially explain linguistic differences in protective effects. Another line of research suggests that bilingualism may mask cognitive decline by enabling reliance on a first language (L1) as a "back-up" system. Méndez and collaborators[31] described this regression to L1 as a protective mechanism, echoing earlier findings[46] that Spanish-speaking MCI patients preferred their first language over English. These phenomena emphasize the interplay between language proficiency and cognitive resilience, underscoring the need for more large-scale, longitudinal research.

Not all findings, however, support a protective role of bilingualism. Chertkow and collaborators[39] failed to replicate Bialystok and collaborators[29], reporting no differences in age of onset or diagnosis between bilinguals and monolinguals. Other studies suggest that the influence of bilingualism varies by cognitive domain: bilinguals with single-domain amnestic MCI showed a 4.5-year diagnostic delay, while no delay was observed in multiple-domain cases[41]. Clare and colleagues[43] further noted that despite a later age at diagnosis, bilinguals exhibited greater impairment upon diagnosis. These results indicate that the protective effect of bilingualism is not uniform across cognitive trajectories.

Additional studies also fail to consistently support bilingualism as a protective factor[38,44-45]. Sociolinguistic context may help explain these mixed

findings, as cultural and environmental factors shape language use and cognitive outcomes. Methodological limitations further complicate interpretation. The age of L2 acquisition is a particularly important variable, since proficiency and critical period effects[47] influence both language mastery and cognitive trajectories. Other challenges include heterogeneity in study populations, variability in language combinations and use, inconsistent outcome measures, and potential publication bias. Importantly, many studies did not adequately control for potentially influential confounding variables such as immigration history, education quality, socioeconomic status, literacy, and healthcare access. These factors are closely tied to CR and may partially account for observed differences between bilingual and monolingual groups.

Another limitation concerns frequency of language use. Not all bilinguals use both languages equally or in cognitively demanding contexts, reducing the cognitive benefits typically associated with bilingualism. Incorporating measures of proficiency, frequency, and context of language use would improve precision in future studies. Relatedly, definitions of bilingualism varied substantially across studies, including differences in proficiency thresholds, age of acquisition, daily use, and reliance on self-report measures. This limits direct comparability across studies and complicates interpretation of bilingualism as a unified construct.

This review also has its own limitations. Despite a comprehensive search, relevant studies may have been missed due to database coverage, keyword variation, or language restrictions. The focus on peer-reviewed English-language studies may have excluded valuable perspectives from gray literature or non-English publications. Additionally, because of substantial heterogeneity in study design, bilingualism definitions, and outcome measures, a formal meta-analysis was not feasible. Findings were therefore synthesized narratively, which may introduce interpretive subjectivity. The descriptive classification of studies as "positive", "negative", or "partial" should be interpreted cautiously, as these categories do not reflect formal quality appraisal or standardized effect estimation.

To advance this field, future research should address heterogeneity in study design, account for age of L2 acquisition and proficiency, and explore the differential impact of bilingualism on specific cognitive domains. Tailored interventions may include bilingual education programs, public health campaigns, and culturally inclusive care. Clinically, it is important to recognize that bilingualism may both delay symptoms and complicate diagnosis, highlighting the need for culturally and linguistically sensitive assessment tools.

In conclusion, this systematic review synthesizes evidence on bilingualism and AD within the framework of CR. The findings support the idea that bilingualism may contribute to a delay in symptom manifestation, but mixed results highlight the complexity of this relationship. Continued research is needed to clarify mechanisms, address methodological challenges, and guide the development of interventions and clinical practices that consider the unique cognitive and cultural profiles of bilingual individuals.

Declaration of Interests Statement

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this article.

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