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BILINGUALISM AND LANGUAGE EDUCATION TO IMPROVE THE COGNITIVE HEALTH OF OLDER PERSONS

ABSTRACT

This article explores whether lifelong bilingualism can be associated with delayed age-related cognitive decline, with cognitive (or brain) reserve as the mechanism that compensates by positively increasing the functional capacity of the brain for older persons. A structural review of recent psychoneurolinguistic studies shows that older bilinguals display several years of delay in dementia symptoms as compared to monolinguals, as well as that positive effects exist in bilingual brain networks, also related to other neurodegenerative disorders. The field is clearly missing an established methodology, nevertheless, lifelong bilingualism can be considered to induce cognitive reserve. Drawing from these implications, we hypothesize that successful ageing could be facilitated by the active use of multiple languages, and in this light, we discuss language education for older persons, the role of Third Age Universities, the implementation of crucial aspects in such courses, and the proper assessment of the effectiveness of language proficiency and cognition.

Keywords: executive function, bilingualism, language education, stroke, older persons

DVOJEZIČNOST IN JEZIKOVNO IZOBRAŽEVANJE ZA IZBOLJŠANJE KOGNITIVNEGA ZDRAVJA STAREJŠIH LJUDI – POVZETEK

V članku raziskujemo, ali lahko vseživljenjsko dvojezičnost povežemo z zamikom starostnega pešanja kognitivnih sposobnosti in kognitivno rezervo kot mehanizmom, ki pozitivno vpliva na možganske zmogljivosti pri starejših ljudeh. Pregled novejših psiho- in nevrolingvističnih študij kaže, da pri starejših dvojezičnih osebah prihaja do večletnega zamika pojava simptomov demence v primerjavi z enojezičnimi osebami ter da obstajajo pozitivni učinki dvojezičnih možganskih mrež, prav tako povezani z drugimi neurodegenerativnimi boleznimi. Na tem področju manjka metodologija, vendar pa lahko vseživljenjsko dvojezičnost povežemo tudi s kognitivno rezervo. Na tej podlagi lahko postavimo hipotezo, da k zdravemu staranju lahko pripomore tudi aktivna raba več jezikov, na podlagi tega pa razpravljamo o jezikovni izobrazbi za starejše ljudi, vlogi univerz za tretje življenjsko obdobje, izvajanju kritičnih vidikov tovrstnih tečajev ter ustrezni oceni učinkovitosti znanja jezikov in kognicije.

Ključne besede: izvršilne funkcije, dvojezičnost, jezikovno izobraževanje, možganska kap, starejši ljudje

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INTRODUCTION

In Slovenia the older subpopulation worries about current and future personal health (Kavčič et al., 2012) and is dissatisfied or has unmet needs regarding health care services (Hlebec, 2018; Hlebec et al., 2016; Pevec & Pisnik, 2018), which altogether might contribute to personal identity crises (Zaletel et al., 2011) and possibly perpetuate cognitive decline later in life. However, educated older persons have shown less expression of narrow social identity (through limited social interactions from a smaller living environment), but more broad social identities formed by a general interest in society (Zaletel et al., 2011). Furthermore, older Slovenian persons that learn languages have mentioned maintenance of cognitive function and social inclusion (Miklič, 2018), love for language and travelling (Zavrl & Radovan, 2016) as reasons to learn new language skills, which might contribute to broad social identities. This might help explain why adults and older persons participate in foreign language courses at Slovenian Third Age Universities (Bizjak, 2010; Miklič, 2018; Sešek, 2012; Zavrl & Radovan, 2016) at what amounts to 49% of all annually offered courses (Sešek, 2012). There has not been much data collected on the cognition of the participants, but this does illustrate that older Slovenians are motivated to learn foreign languages.

This paper explores whether the use of multiple languages through life can improve cognitive health. An initial milestone paper by Bialystok et al. (2007) posed that lifelong bilingualism delays the onset of dementia, and several studies have been arguing in favour or against this ever since.

Thus, we will explore the population studies addressing the association between bilingualism and a delay in dementia, investigate the changes in brain physiology as corresponding neurobiological evidence, and describe the effects bilingualism has on other neurological disorders. Finally, we will also discuss empirical studies evaluating language education in older persons. With the goal of inducing beneficial health effects for the older population, recommendations are provided for implementing psycholinguistic research and language education for older persons at Third Age Universities.

THEORETICAL BACKGROUND

The active control of using multiple languages is a unique feature of humans. Language proficiency (speaking, listening, reading and writing) has been correlated to enhanced cognition (e.g. Diamond, 2013) as well as to a beneficial influence on children's cognitive development (e.g. Kovács & Mehler, 2009). The reason is that language contributes to behaviour, and in turn, behaviour is controlled by cognitive processes, often called executive functions. Examples of executive functions include attention, inhibition, working memory, planning, fluid intelligence, etc. (Diamond, 2013), and they are also involved in obtaining language proficiency.

Proficiencies in multiple languages acquired over a person's lifetime lead to bi- and multilingualism. These have been noted to enhance cognition, and although their effects are

somewhat muted in adulthood (Bialystok et al., 2012), a discussion has recently emerged on the benefits of life-long bilingualism and its effectiveness in older adulthood. A study by Bialystok et al. (2007) is the basis of this discussion. The authors suggest that lifelong bilingualism protects against age-related cognitive decline and may even postpone the onset of dementia symptoms. The lifelong exposure to, and the use of multiple languages, is supposed to be building up cognitive reserve.

Cognitive or brain reserve is a hypothetical definition which poses that through cognitive training the brain becomes more efficient, various parts will be more strongly connected, alternative pathways are used to execute brain functions, and eventually because of this, the brain is able to cope better with damage, infection, and disease (Stern, 2002). Over the last few decades, it has been proposed that cognitive reserve can be induced by several factors, like continual engagement in stimulating physical, intellectual, and social activities (Stern, 2012). Nowadays these factors are known to maintain cognitive functioning important for successful ageing, and well-known co-factors that play crucial roles include level of education, occupational status, and socio-economic class.

RESEARCH METHODOLOGY

The search strategy and literature selection process followed the protocol of *preferred reporting items for systematic reviews and meta-analysis* (Moher et al., 2009). The following databases were searched: PubMed Medical Information System, Web of Science, and ScienceDirect, using a combination of keywords: bilingualism, language, older person, elderly, dementia, cognitive reserve. Studies needed to be published within the last 15 years and have reported the average age and number of older persons with distinction between monolinguals and bilinguals, and basic language proficiency.

DOES LIFELONG BILINGUALISM DELAY DEMENTIA?

The initial epidemiological study by Bialystok et al. (2007) affiliated with universities and health networks in Toronto, Canada, noticed that among immigrants who had been diagnosed with dementia but showed equal levels of cognition, monolinguals were clinically diagnosed with dementia at the average age of 75.4 years, versus 78.6 years for bilinguals, with no differences between the genders. In other words, the bilinguals experienced the onset symptoms later, and were diagnosed for dementia approximately 4.1 years later than the monolinguals.

In another independent Canadian immigrant study by Chertkow et al. (2010), the diagnosis of Alzheimer's disease-related dementia (ADRD) was delayed by almost 5 years in immigrants and in non-immigrants whose first language was French, but not for non-immigrants whose first language was English. In general, a small but significant protective effect was found in people who spoke more than two languages (Chertkow et al., 2010), where no gender differences were found. Bialystok et al. (2007) followed up their research with another set of English immigrants, but now only diagnosed with

probable ADRD (Craik et al., 2010), and again the bilingual patients were diagnosed 4.3 years later and reported the onset of symptoms 5.1 years later than the monolingual patients.

The studies that followed focused on non-immigrant populations. In California, the United States of America, a study among Spanish-English bilinguals who had been diagnosed with probable ADRD showed that a higher degree of bilingualism was associated with later ages of onset and diagnosis, although only in the less-educated patients (Gollan et al., 2011). In India, bilinguals speaking either Telugu, Hindi, Dakhini, English, or a combination, developed ADRD on average 4.5 years later than monolinguals (Alladi et al., 2013), even in illiterate individuals, indicating that the difference in onset of dementia likely was not the effect of education, but better developed cognitive skills.

However, three large prospective cohorts from North America (Lawton et al., 2015; Yeung et al., 2014; Zahodne et al., 2014) did not find associations between bilingualism and the risk for dementia, irrespective of whether bilingualism was measured by self-reporting or an objective test. An explanation for the findings of these three large prospective cohorts perhaps lies in the previously mentioned study by Gollan et al. (2011), where it was reported that the relation of increasing levels of bilingualism were associated with increasingly later ages of diagnosis and onset of symptoms among Spanish-English bilinguals only in low-educated bilinguals, while no such effect was observed in higher educated subjects (although no monolingual control group was included and the sample size was small). For the large cohorts, education was not reported to influence the association of bilingualism and the onset of dementia symptoms, however, the levels of education were not reported in detail.

These studies were predominantly of a retrospective nature, that is, where the researchers grouped the subjects based on their exposure data and in retrospect compared the incidences of dementia. Recently, two prospective cohort studies were published where the baseline exposure data were collected before any of the subjects had developed any form of dementia. Thus, during a year of clinical monitoring, Bialystok et al. (2014) in Canada and Woumans et al. (2015) in Belgium confirmed that compared to monolingual subjects, bilingual ones were several years older in both age of dementia symptoms manifestation and the date of their first clinical diagnosis. Both studies observed a delay for bilinguals in manifestation and in diagnosis (about 5 years) for French-English and French-Dutch respectively, independent of gender and other lifestyle factors. Additionally, various executive functions were tested, of which the evaluated performances were comparable on the first occasion, while over the year of observation, similar declines in both mono and bilinguals were observed (Bialystok et al., 2014; Woumans et al., 2015).

However, some groups found conflicting results, challenging the relation and making the topic controversial. For example, a study from the U.K. among a Welsh-English

population (Clare et al., 2016) did not find a significant delay in the onset of dementia in bilinguals and monolinguals. At the age of diagnosis, the bilinguals had 3 years of difference (but not statistically significant), at which point they were already cognitively impaired, but did not differ significantly in executive functions (besides, over time some bilingual executive functions remained at a higher strength level).

In addition, another retrospective study with a New York ageing cohort (with self-reported language proficiency) was investigated by Sanders et al. (2012) and concluded that bilingualism does not have an independent protective effect against dementia, but rather induced a small non-significant increase of the risk to develop dementia, and higher education further enhances this risk. An Australian study with a large cohort spanning 20 years also concluded that quantity and quality of education, and not bilingualism, are a predictor of cognitive decline (Mukadam et al., 2018). Gollan et al. (2011) suggested that the power of cognitive reserve for delaying ADRD, particularly for higher educated bilinguals, did not have a further effect, and they posed that there had to be an upper limit on the amount of cognitive reserve. A recent meta-analysis on the pooled data of several of the above-described prospective cohorts by Mukadam et al. (2017) gave a combined odds ratio of dementia of 0.96 in bilinguals compared to monolinguals. However, Mukadam et al.'s statistical and methodological approach was heavily debated (e.g. Woumans et al., 2017).

Due to incomplete information gathered by these prospective and retrospective studies, the psycholinguistic field initialised an on-going public discussion that has addressed some inconsistencies regarding the methodological issues for this kind of psycholinguistic research. To eliminate controversy in future studies, the following methodological aspects need to be aligned: 1) the level of bilingualism or multilingualism and its lifetime span need to be determined properly, based on objective language proficiency tests; 2) standard cognitive test batteries addressing various executive functions need to be implemented that generate comparable datasets; 3) detailed information on the education of the participants (both in time and degrees) are needed; 4) new longitudinal studies fulfilling these basic methodologies need to be performed.

Nevertheless, from the studies on about 2000 patients with reasonable assessment of both language proficiency and dementia incidences (summarised in Table 1), it is possible to draw a preliminary conclusion that bilingualism (or multilingualism) might be an effective cognitive lifestyle to significantly delay the onset of ADRD symptoms (4 to 5 years), irrespective of gender, various lifestyle factors, or the combination of language proficiencies.

Table 1

Overview of the research papers' study characteristics regarding lifelong bilingualism and dementia

Study	Study type, number of participants, (N), description of persons, bilinguals (B), monolinguals (M), average age (y), percentage female (%)	Name of study and organisation, country, time period, first and other languages	Impact of lifelong bilingualism on dementia
Alladi et al. (2013)	Retrospective; N=650, dementia registered older patients, 66.2y, 35%; M=257, 61.1y, 49%; B=391, 65.6y, 35%	Memory Clinic of a university hospital in Hyderabad, India, between 2006-2012; Telugu, Dakhini, Hindi, English	B developed dementia 4.5y later than M; significant difference in age at onset ADRD as well as frontotemporal and vascular dementias, also observed in illiterate patients; no additional benefit to speaking more than 2 languages.
Bialystok et al. (2007)	Retrospective records analysis of cohort; N=184, 90% older immigrants; M=91, 75.4y, 53%; B=93, 78.6y; 59%	Memory Clinic at Baycrest, Toronto, Canada, between 2000-2005; French, English, Polish, Yiddish, German, Romanian, Hungarian	B significant difference of 4.1y later age of onset of dementia symptoms; B were 3.2y older than M at the time of initial clinic appointment; delayed onset of symptoms for B significant in probable ADRD patients (delay of 4.3y), for other dementias, with 3.5y delay; no difference in the rate of cognitive decline between B and M.
Bialystok et al. (2014)	Longitudinal; N=149, older MCI or ADRD diagnosed patients; M=73, 52%; B=76, 55%	Sam and Ida Ross Memory Clinic at Baycrest, Toronto, Canada, with 3 sessions over one y; French, English	B several years older than M at age of symptom onset (4.7y for MCI, 7.3y for ADRD) and date of first clinic visit (3.5y for MCI, 7.2y for ADRD), independent of lifestyle variables; first testing, performance on the EF tasks comparable between M and B; EF performance declined over 3 sessions, but no differences in the rate of decline between M and B.
Cherthow et al (2010)	Retrospective records analysis of cohort; N=632, older immigrants and non-immigrants; M=379, 76.7y, 63%; B=253, 77.6y; 52%	Memory Clinic of the Jewish General Hospital, Montreal, Canada, between 1997-2006; French, English, Canadian aboriginal languages	Non-significant 1.0y difference, with B having symptom onset slightly later; immigrant B were diagnosed 5.1 y later than M; non-immigrant B, the difference was significant, with M having dementia diagnosis 2.6 years later than B; no difference in rate of cognitive decline between B and M.

Study	Study type, number of participants, (N), description of persons, bilinguals (B), monolinguals (M), average age (y), percentage female (%)	Name of study and organisation, country, time period, first and other languages	Impact of lifelong bilingualism on dementia
Claire et al. (2016)	Cross-sectional cohort; N=86, older diagnosed ADRD patients; M=49, 78.8y, 45%; B=37, 80.8y, 57%	Memory Clinics in North Wales, United Kingdom; Welsh, English	Non-significant difference in age at time of diagnosis; B 3y older than M, but B were significantly more cognitively impaired at time of diagnosis; no significant differences between M and B in EF tests; B appeared to show relative strengths in the domain of inhibition and response conflict.
Craik et al. (2010)	Longitudinal; N=211; diagnosed with probable ADRD; M=109, 72.6y, 55%; B=102, 77.7y, 58%	Sam and Ida Ross Memory Clinic at Baycrest, Toronto, Canada, between 2007–2009; English, Yiddish, Polish, Italian, Hungarian, French, other languages	B diagnosed 4.3y later; B onset symptoms reported 5.1y later; equivalent cognitive level; no immigration effect; M received more formal education.
Gollan et al. (2011)	Retrospective longitudinal; N=44, Hispanic older persons; B prefer English=22, 75.1y; B prefer Spanish=22, 77.1y	University of California, San Diego Alzheimer's Disease Research Center, San Diego, California, United States, between 2002–2007; Spanish, English	Higher degrees of bilingualism associated with increasingly later age-of-diagnosis and age of onset of symptoms; significant interaction between years of education and bilingualism.
Lawton et al. (2015)	Retrospective cross-sectional; N=1777, 80.5y, immigrant and U.S.-born, Hispanic Americans; M=1152; B=625	Latino Study on Aging, Sacramento, Sacramento Area, California, United States, between 1988–2008; Spanish, English	Mean age of dementia diagnosis was not significantly different for B, M; B dementia cases were significantly better educated than M; US-born B and M did not differ significantly in education.
Mukadam et al. (2018)	Retrospective longitudinal; N=2087, older participants, 65y; M=1901; B=186	Australian Longitudinal Study of Ageing, Adelaide, South-Australia between 1992–2014; English, other languages	B lower baseline MMSE scores than M, explained by education that partly explained baseline EF test scores differences; B and M did not differ in MMSE decline over time nor on baseline EF tests.

Study	Study type, number of participants, (N), description of persons, bilinguals (B), monolinguals (M), average age (y), percentage female (%)	Name of study and organisation, country, time period, first and other languages	Impact of lifelong bilingualism on dementia
Sanders et al. (2012)	Retrospective longitudinal, N = 1779, older citizens, 78.6y, 61%; M=1389, 78.3y, 61%; B=390, 79.4y, 61%	Einstein Aging Study at Bronx, New York, United States, between 1993-2010; English, non-native English speakers	No statistically-significant association between non-native English speaking and incident dementia or ADRD; increased risk of dementia for non-native English speakers with ≥16 years of education.
Woumans et al. (2015)	Longitudinal; N=134, new probable ADRD patients; M=69, 76.4y, 70%; B=65, 77.9y, 70%	Ghent University Hospital and Brussels University Hospital, Ghent and Brussels, Belgium, between 2013-2014; French, Dutch, English, German, other languages	Significant delay for B of 4.6y in manifestation and 4.8y in diagnosis.
Yeung et al. (2014)	Retrospective cross-sectional; N=1616; community-dwelling older persons; M=913; 77.4y, 60%; B=703; 77.1y, 58%	Canadian Study of Health and Aging, Manitoba, Canada, between 1991-1997; English, French and other bilingual	B had lower education, lower 3MS scores, more subjective memory loss, and more likely to be diagnosed with cognitive impairment; B no dementia at both two timepoints compared with M; no association between B and dementia at first timepoint; no association between B and dementia at second timepoint.
Zahodne et al. (2014)	Retrospective cross-sectional; N=1067, Spanish emigrants; M=637, 75.7y, 72%; B=430, 74.9y, 64%	Washington/Hamilton Heights Inwood Columbia Aging Project, Northern Manhattan, Washington, United States between 1992-1999; Spanish, English	B associated better memory and executive function at baseline; B not independently associated with rates of cognitive decline or dementia conversion.

Note. ADRD = Alzheimer's Disease-Related Dementia; 3MS = modified MMSE; EF = Executive Function; MCI = Mild Cognitive Impairment; MMSE = Mini-Mental State Examination; y = year

BRAIN STRUCTURES AND THEIR RELEVANCE TO LANGUAGE AND BILINGUALISM

It is especially important to discuss cognitive brain reserve in connection with the human trait of highly evolved language proficiency. In the last few decades, our understanding of the brain's functionality has dramatically improved, and we know about the brain's

plasticity, meaning it adapts its functionality to repeated stimuli and/or activities. Learning and memory processes are a good example of research with repeated natural stimuli that has yielded profound understanding of changes in the brain at the neuronal level and their networks, identifying essential adapted biochemical pathways (e.g. Ramakers et al., 1997).

Although the brain circuits, structures, and the corresponding executive functions activated with language usage are not fully understood or identified and might in fact vary for the different ages (Mohades et al., 2015), the brain areas presumed to be potentially involved will be discussed, and if possible, the observed neuroanatomical changes therein coinciding with the use of multiple languages.

Two networks are presumed to play important but distinct roles during language processes. The *executive control network (ECN)* is generally associated with focused cognitive tasks, working memory, control processes and other executive functions, and links dorsolateral frontal and parietal neocortices. During many cognitive tasks when the *ECN* is activated, the *default mode network (DMN)* shows reduced activity (Crittenden et al., 2015). The *DMN* is a widely distributed connected network of brain areas influencing behaviour and non-focused tasks, with presumed modulating roles in language processing: in dementia patients with AD/AR, the *DMN* is often being negatively affected, but for bilinguals the *DMN* has been shown to be increasingly connected (Grady et al., 2015; Perani et al., 2017).

Within the *executive control network*, language control is determined by the activation of the following areas: the *temporal-parietal cortex*, with the classic *Broca* and *Wernicke* areas (important in speech production and speech comprehension as well as various non-language cognitive tasks), is responsible for maintaining the target of conversation; the *left prefrontal cortex* updates the language, inhibits the language that is not being used, and corrects errors (Luk et al., 2010, 2011). From studying young bilingual subjects, it is believed that the *anterior cingulate cortex* monitors the selection of the correct language and verifies whether language and requirement are matching, i.e., conflict monitoring (Abutalebi et al., 2012). The activity of the *anterior cingulate cortex* increases while switching languages, and it communicates with other areas of the brain, among others the subcortical areas, the *nucleus caudatus*, and the *basal ganglia*, including the left *putamen*, which supervise language selection. Their activities vary with language proficiency, while the switch from most to least proficiently spoken language triggers the highest activity (Abutalebi et al., 2013a; 2013b). These subcortical areas can in turn modulate the activity of the *prefrontal cortex* (Luk et al., 2011). The hippocampus (one in each hemisphere) is part of the subcortical limbic system and crucial for language learning since both short- and long-term memory depend on its activity.

Brain areas are generally composed of white and grey matter. While grey matter contains the neuronal cell bodies, dendrites, and the axon terminals with the synapses, white matter contains the axons connecting the different areas of grey matter to each other. In

bilinguals with probable ADRD atrophy was substantially greater in the temporal areas as compared to monolinguals with ADRD (Schweizer et al., 2012). However, Gasquoine (2016) correctly points out that the bilingual research has yielded inconsistencies in white and grey matter changes (and/or their relation to executive functioning). A reason would be that straightforward interpretation was hindered because the research conducted until then comprised predominantly young bilinguals, while only recently older subjects have been investigated in more detail. Recent studies with older subjects have noticed that bilinguals and monolinguals overall did not differ in grey matter volume (Borsa et al., 2018; Gold et al., 2013a; Olsen et al., 2015). It has been noted that more grey matter is present in the *dorsolateral prefrontal cortex* of bilinguals (Abutalebi et al., 2015), with greater frontal lobe white matter volume (Olsen et al., 2015), despite bilinguals showing lower white matter integrity (Gold et al., 2013a). An explanation for the latter findings is that changes in brain integrity and volume could represent different processes of atrophy, occurring at different times. Nevertheless, recent reviews, taking more relevant studies into account, have concluded that bilinguals show overall better-preserved grey and white matters (Pliatsikas, 2019), with structural changes in language-relevant brain areas (Hayakawa & Marian, 2019), among others larger hippocampal volumes (Voits et al., 2020).

For monolinguals, the thickness of temporal pole cortices was smaller with advancing age (Olsen et al., 2015), which was not observed for bilinguals. In addition, it was shown that older bilinguals with ADRD had higher tissue densities and thicker cortices in medial-temporal areas than age-matched monolinguals (Anderson et al., 2018; Duncan et al., 2018).

On the matter of executive functioning, age-related performance reductions were observed while comparing older and younger bilinguals (Gold et al., 2013b). Older bilinguals outperformed their age-matched monolinguals. Furthermore, older bilinguals displayed decreased activation in the *left frontal cortex* and *cingulate cortex* as compared to age- and cognitively matched older monolinguals, and this was directly correlated to better task-switching performance (Gold et al., 2013b). In line with this are the functional magnetic resonance imaging scans during the performance of the Simon task, a switching and response task depending on the ability to suppress irrelevant information. Older bilinguals as compared to older monolingual persons typically did not recruit frontal brain areas, instead predominantly activating the left inferior parietal area (Ansaldo et al., 2015), a typical opposite of the posterior-anterior shift observed in normal ageing. The review by Pliatsikas (2019) concludes that bilinguals with ADRD who perform equally well in cognitive tests as monolinguals do show less severe neurodegeneration. This is also reflected in that bilinguals who do have larger hippocampi do not perform better when it comes to episodic memory (Voits et al., 2020).

A posterior-anterior shift, combined with increased connectivity in both the *DMN* and *ECN*, is a classic brain feature believed to be a compensation mechanism in ageing persons (Ansaldo et al., 2015; Gold, 2015; Perani et al., 2017). While monolingual seniors have an extended and bilateral pattern of neuronal decline with age, bilingual seniors show a less-extended and only leftward pattern of age related effects (Borsa et al., 2018).

Besides, in bilingual patients with probable ADRD (Perani et al., 2017), metabolic hypoconnectivity patterns were observed that significantly correlated with the degree of lifelong bilingualism (Perani et al., 2017), corresponding to the brain areas mentioned for the leftward age decline by Borsa et al. (2018). For bilinguals, the connectivity was increased bilaterally in frontoparietal areas, as well as for specific language areas in the right-hemisphere (Gold, 2015; Perani et al., 2017).

In conclusion, there are structural changes of critical right hemispheres of the *ECN* for older bilinguals, and the absence of the posterior-anterior shift, but enhanced connectivities and thicker neocortices in both the *DMN* and *ECN* in ageing bilinguals. In combination with the delay in onset/manifestation of dementia and the positive assessments of the executive functions for bilinguals, these would indeed suggest that bilinguals wait longer before attending a clinic, as they rely longer on their more connected brain structures formed by active multiple language use during their life, possibly inducing cognitive reserve.

BILINGUALISM-INDUCED NEUROPROTECTIVE EFFECTS IN OTHER NEUROLOGICAL DISORDERS

As pointed out in the previous paragraphs, lifelong bilingualism seems to be associated with a later onset of dementia, and with a structurally changed and more connected, perhaps more resilient brain. This raises the question whether life-long bilingualism affects the incidence or severity of neurological disorders other than dementia later in life.

Besides bilingualism delaying ADRD for 3.2 years (Alladi et al., 2013), the same study from India also reports delays in other dementias, for example, vascular dementia for 3.7 years, where different cellular structures are targeted and which is often associated with a high incidence of stroke. A sudden limitation of blood supply to certain parts of the brain deprives the neurons of oxygen and nutrients causing cellular damage, and if it is too long or too severe, irreversible neuronal cell death. The vascular risk factor might be different for higher lifelong language proficiency. Thus, Ischemic stroke patients were retrospectively evaluated by a clinical research centre (Alladi et al., 2016) and showed a twice as high percentage of patients with intact cognitive functions after stroke for bilinguals as compared to monolinguals. This suggests that bilingualism has a protective role in post-stroke cognitive impairment.

Frontotemporal dementia was also delayed for 6.0 years (Alladi et al., 2013). Here the frontal and the lateral parts of the brain, the areas coinciding with the maintenance and control of language, are affected by neuronal death. Alladi and colleagues diagnosed 193 patients with frontotemporal dementia syndromes over a decade (Alladi et al., 2017). Especially the age of onset of the behavioural type of frontotemporal dementia was significantly delayed for as long as 5.7 years, independently of other factors like education and gender (Alladi et al., 2017). However, this was not the case for other types of frontotemporal dementia, including motor neuron disease with a delay of (merely) 3 years, and only 0.7 years for the aphasia type, where the language comprehension and production

are affected due to brain damage in the left hemisphere (indirectly due to the trauma of the disease which is often a stroke).

Parkinson's disease is a motor-neurodegenerative disorder in which the dopaminergic producing neurons of the *substantia nigra* face early neuronal death during a person's life. This usually affects the person's movement, gait, and balance, as well as causes rigidity and tremors; the consequences of these manifestations are often fatal. Since the *substantia nigra*, one of the basal ganglia, is affected and plays a crucial role in the supervision of language selection and modulation of the activity of the prefrontal cortex (see previous section), language might be impaired beside additional executive functions. A cross-sectional cohort among a Welsh-English population of Parkinson's disease patients (Hindle et al., 2015) showed that the monolinguals performed better in the language tests. Moreover, despite the finding that the bilingual Parkinson's disease patients did not perform better in overall executive control tasks than the monolingual Parkinson's patients, the degree of bilingualism correlated with better nonverbal reasoning and better working memory (Hindle et al., 2015). In contrast, among a population of Catalan-Spanish bilinguals, Parkinson's patients showed decreased processing speed, less accuracy and more errors in language switching tasks as compared to healthy non-Parkinson's bilinguals (Cattaneo et al., 2015). It was noted that these abilities of language control became impaired only when the non-linguistic abilities were affected by the disease. This suggests that some mechanisms of bilingual language control are not necessarily dependent on the *ECN* (Cattaneo et al., 2015). Because these performances were not compared to healthy executive functions and the properties of monolingual control networks, the effects of life-long bilingualism on Parkinson's disease remain largely unexplored.

Another neurodegenerative disorder, Huntington's, is heritable, and causes neuronal cell death in the basal ganglia, *nucleus caudatus*, and *putamen*, and eventually in the *cerebral cortex* as well. Changes in mood and mental abilities are often the earliest symptoms, while later failure of both coordination and gait occur. Martínez-Horta et al. (2019) thoroughly investigated the brain structures and executive functions of Spanish-Catalan bilinguals and concluded that the higher use of bilingualism moderates the degree of neural integrity, giving rise to higher grey matter volumes in multiple frontotemporal regions. These life-induced changes had a significantly better impact on task performances like inhibition, attention and anticipation, monitoring and task-switching; they also contributed to better preserved motor and functional capacity among the Huntington's patients (Martínez-Horta et al., 2019). These results hint at some cognitive advantage induced through life-long bilingualism for Huntington's disorder patients.

Looking at these various neurological disorders, it seems that life-long bilingualism does make the ageing brain more connected, strengthened through essential trajectories, and thus, in general creates a brain capable of coping with the damage of neurological disorders for longer. In other words, bilingualism does induce some form of cognitive reserve. Unfortunately, descriptions of the effects of lifelong bilingualism on most clinical neurodegenerative disorders (other than dementia) have been limited.

PLANNING LANGUAGE EDUCATION AS A NEUROPROTECTIVE MEASURE FOR OLDER PERSONS

Despite positive associations of language proficiency and early life cognition (Diamond, 2013; Kovács & Mehler, 2009), associations between language learning and cognitive advantages for later in life are under investigation (Poissnel et al., 2018), but are mostly embedded in earlier literature.

Bak et al. (2014) tested the influence of bilingualism in 853 participants over 63 years and showed a positive effect of bilingualism on old age cognition, including for those who acquired their second language in adulthood (Bak et al., 2014). In addition, a retrospective cohort in the U.S.A. investigated whether language education before the age of 18 was associated with the risk of developing mild cognitive decline (Wilson et al., 2015). The results showed that higher levels of foreign language instruction during childhood were associated with lower risk of developing cognitive decline in old age but not with the rate of decline.

An English-French technology-based language learning programme in which 14 older French persons participated, attending 16 2-hour sessions over a period of 4 months (Ware et al., 2017), showed that the scores for both cognition and subjective feelings of loneliness and social isolation at post-intervention did not change. Yet the intervention was perceived as difficult, enjoyable, and stimulating. Bak et al. (2016) showed that attending a Scottish-Gaelic language course once per week for 5 hours for 3 weeks improved the attention in the older persons compared to non-attendants. Meanwhile, 4 hours or less per week showed an inconsistent pattern: some improved but others stayed the same or deteriorated. However, a recent study with monolingual older persons attending a Spanish-Basque language course for 5.5 hours for over 8 months (Ramos et al., 2017), and older Telugu-English bilinguals (Mishra et al., 2019) did not show any difference between cognition or performances in switching paradigms. On the other hand, a study with older Dutch-Frisian bilinguals reported to switching often between the two languages as active bilinguals, did show significant differences in switching paradigms in favour of the bilinguals (Houtzager et al., 2017). This discrepancy in switching results is explained in that bilinguals may not often use skills like shifting, switching, inhibition, or monitoring and that only the on-going practice of these skills through active usage of bilingualism may modulate executive control (Houtzager et al., 2017). In other words, the active use of two languages, and not just passive exposure to them, requires the activation of essential cognitive mechanisms (Borsa et al., 2018). It is important to note that only such cognitive challenges then translate into better performance on tasks measuring individual cognitive components, including switching paradigms, once proficiency is levelled up (that is, later in life). This is important to consider in designing a study, since to investigate bilingual advantages through language education, the study needs to include a protocol to properly assess certain functions.

Thus, to have older persons learn a new language up to proficiency, continue to practice active bilingualism, and subsequently contribute to building up cognitive reserve, one

needs to carefully plan the learning paradigm. The following recommendations build on previous notions (Miklič, 2018; Zavrl & Radovan, 2016) and further research is needed to propose proper and effective methodologies that fulfil these recommendations: 1) establish personal difficulties and make sure the older person's auditory and visual perceptions are not hindered during classes; 2) incorporate abundant time within the period of learning (preferably long, not flash courses); 3) add multiple contact hours with repetitions during the educational period (preferably hours scattered over several days a week for effective memorisation); and 4) challenge the participants by using multiple languages during the assignments to demand shifting, switching, and inhibition activities. Moreover, language education for older persons needs to be approached differently from other age groups. Hence, 5) courses need to fulfil a personal service to each participant and therefore course materials and interactions depend on the participants' personal experiences and acquired knowledge, and 6) the content for a class will be challenging to prepare and compile, and should be much more varied in nature. Besides, 7) depending on the objectives of both the teacher and the participant, the improvement of language proficiency and cognitive abilities, and/or life satisfaction requires a clear and detailed assessment plan of the effectiveness of both language learning and cognition. The present review clearly indicates that the field of psychoneurolinguistics has only recently started to develop such criteria.

CONCLUSIONS

The current paper presents evidence that life-long bilingualism will provide the older brain with stronger neural pathways to cope better with neurological damage. Consequently, it is suggested that learning an additional foreign language at later ages might follow that relation, provided the second language will be maintained and actively used.

The small Republic of Slovenia, situated in the heart of Europe and surrounded by larger countries, is a multilingual nation and the use of multiple languages is very common. Two of its border regions are officially bilingual: Hungarian and Italian are publicly used and protected, while many more languages are spoken and many dialects can be found over several generations. Like in other parts of Europe, in the future these might be recognized as separate languages, more or less distinct from the official language. This multilingual aspect of Slovenia is reflected in that older Slovenian adults are very motivated to learn foreign languages (Miklič, 2018; Sešek, 2012) and the number of potential students of language courses conducted by the Third Age University could number a few thousand annually (Sešek, 2012). There is an opportunity for Third Age Universities to act as social gathering points and places to learn new or maintain and upgrade foreign language skills beneficial for one's personal brain health. The motivation for participating ranges from love of languages to the maintenance of cognitive abilities (Bizjak, 2010; Miklič, 2018; Sešek, 2012; Zavrl & Radovan, 2016), but the effectiveness in the long-term has not been evaluated in terms of cognition or life satisfaction (Bizjak, 2010; Miklič, 2018; Sešek, 2012; Zavrl & Radovan, 2016). Third Age Universities should link their adult education

process to a more scientific evaluation through standardised language proficiency and cognitive test batteries, and establish collaborations with psycholinguistic and social fields. After all, the positive long-term effects on cognition and life satisfaction language courses have for older persons in terms of contributing to brain health and the public health perspective would be widely applicable, socially, and economically relevant, and cost effective as well.

Slovenian Third Age Universities can contribute to increasing general public health. An unconscious will to maintain one's cognitive abilities might be contagious as less socially active older persons might be persuaded more easily to join their friends and participate. The Universities can adapt their courses to be socially and cognitively challenging for various social backgrounds, and in this way, the older subpopulations might undergo reductions in social isolation and an increase in self-confidence, leading to better cognitive health. Foreign language instruction and its effectiveness, in collaboration with academia, provides an opportunity to emphasize the benefits of such courses and present them as a neuroprotective advantage contributing to better brain health. Besides, the older population might gain more appreciation within society for providing evidence of the potential benefits of bilingualism and/or its neuroprotective advantages, while the adult education process will become more widely appreciated as socially relevant.

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