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Bilingualism and the Declining Brain

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Potential cognitive and neurological effects of bilingualism constitute very timely topics, which have been receiving increasing scientific interest over the last two decades. For some time, bilingualism and its effects on non-linguistic cognition have been subject of discussions and fervent debates, especially with respect to bilingualism effects in older age. The available literature remains limited, and it has largely focused on the effects of bilingualism on executive functions, a set of cognitive abilities encompassing response inhibition, mental set-shifting, and information updating – all needed in the control of two or more languages. For these functions, bilingual individuals have often been shown to exhibit increased efficiency compared to monolinguals (Valian, 2015). Moreover, neuroimaging studies have revealed bilingualism-induced changes in the brain too, including both functional and neuroanatomical changes, that might even lead to better preserved brains in older life (or a *brain reserve*; Pliatsikas, 2020; Pliatsikas & Luk, 2016).

The findings of bilingualism as a factor leading to changes in the brain and cognition have not been discussed only in the context of healthy ageing. There are suggestions that bilingualism induces a *cognitive reserve* in patients with neurodegenerative diseases, expressed as relatively well preserved cognitive functionality in the face of brain degeneration. Other studies have shown that bilingualism might even delay the onset of Alzheimer's Disease symptoms by 4-5 years (for a review, see Voits, Pliatsikas, Robson, & Rothman, submitted). Therefore, if bilingualism is a factor that carries weight in clinical contexts, it is extremely important to ask questions about the exact nature of the neural mechanisms bilingualism engages with and helps protect with respect to neurodegeneration onset.

The collection of papers in the present special issue not only presents fresh empirical evidence but also includes important theoretical and practical suggestions on how to move

forward this emerging but promising field.¹ In particular, this issue comprises empirical papers on healthy ageing and clinical neurodegeneration, as well as opinion articles from experts in the field.

In an opinion paper, Bialystok, Anderson, and Grundy (2020) review the available evidence for and against cognitive reserve in bilingualism. They strongly argue that cognitive reserve cannot be evaluated on the basis of behavioural data only, but appropriate brain measures (structure and/or function) should also be studied and presented. The authors also argue that using standardised dementia screening tests alone might not fully capture the cognitive abilities of *healthy* ageing samples, as they are very likely to score at ceiling, so more elaborate cognitive testing is necessary; on the other hand, a clinical diagnosis (e.g. of Alzheimer's disease or stroke) might be a better marker of cognitive abilities, which in itself, and in conjunction with brain measures, can function as a more reliable criterion in assessing whether the *clinical* sample under investigation demonstrates cognitive reserve. The authors propose that an appropriate experimental design in the study of cognitive reserve in bilingualism should involve two well-matched groups (bilinguals and monolinguals) who are followed over a long period of time with a comprehensive testing battery including both cognitive and brain measures.

In another opinion paper, Del Maschio, Fedeli, and Abutalebi (2020) maintain that bilingualism should not be dismissed as a source of cognitive and brain reserve. While acknowledging the inconsistent findings in the field, the authors argue that several factors have to be taken into account in order to understand these inconsistencies. One of these factors is how bilingualism is defined and operationalised across different studies, and whether quantitative and qualitative aspects of bilingualism are considered that may result in different

¹ This issue was inspired by the 2017 workshop on Bi-/Multilingualism and the Declining brain held at the Centre for Literacy and Multilingualism (University of Reading, UK), which brought together psychologists, neuroscientists, clinicians and linguists working on the effects of bilingualism on the declining brain, including in healthy ageing and in progressive and acute neurodegenerative conditions.

outcomes in cognition and brain structure and function (see also Pliatsikas, DeLuca, & Voits, 2019). Another factor is the difference in experimental designs, sampling procedures and the treatment of potential extraneous variables that might relate to cognitive and brain adaptations, especially in designs that employ cross-sectional designs (e.g., bilinguals vs. monolinguals or young vs. old bilinguals) with a single test point. Such variables include education, occupation and socioeconomic status of the tested samples, as well as their habits and leisure activities, which might tap the same resources that bilingualism does, and consequently confer similar outcomes. The authors conclude that bilingualism could still be treated as factor that can potentially counteract brain decline, at least to the extent that it is an active experience, and it should be viewed on a par with other activities that are also thought to deliver beneficial cognitive and brain outcomes.

Moving on to the empirical papers of this issue, Dash, Berroir, Ghazi-Saidi, Adrover-Roig, and Ansaldo (2020) administered a Simon task during fMRI scanning to test how and whether healthy ageing bilinguals and monolinguals differ in terms of different modes of cognitive control as described in the Dual Mechanisms of Control framework (Braver, 2012); specifically, the proactive mode, which uses context predictively to prepare the cognitive system for future events, and the reactive mode, which responds to presence of events retrospectively by reactivating previously stored information. The proactive and reactive control modes are indexed by fast and low responses, respectively. There was a bilingual advantage specifically on the proactive control mode, and this was accompanied by a significant activation in the insula, whose role on the proactive mode of control is well-known (Jiang et al., 2015). As for monolinguals, they recruited a vast network showing lower efficiency in this proactive mode. The opposite pattern was observed in the reactive mode of control, i.e., slower responses, with larger activation patterns in bilinguals compared to monolinguals. The authors propose that reliance on reactive and proactive modes of control might vary with

language experiences: in bilinguals, the proactive mode is the preferred mode of cognitive control, and it seems to benefit more from bilingual experience; in contrast, as the dispreferred mode, the reactive mode of control engages a greater network of regions in bilinguals.

In another study looking at healthy bilingual older adults, Titone, Mercier, Sudarshan, Pivneva, Gullifer and Baum(2020) examine the efficiency of bilingual language control via an eye-tracking study, testing for interference effects elicited by the presence of between-language and within-language phonological competitors to a target stimulus. In each trial, the participants were presented with multiple visual stimuli one of which had to be matched with a single auditory stimulus. Among the visual stimuli presented were the target stimulus, control items, and phonological competitors, which are also co-activated as the acoustic signal unfolds. To successfully complete this task, participants need to inhibit competing representations when selecting the appropriate stimulus. The participants in this study were younger and older English-French bilinguals of varying language dominance that were matched on various measures of second language acquisition and use. The results of this study indicate that age is a factor predicting increased within-language phonological competition. A similar trend was observed for between-language competition. In sum, this contribution sheds light on how age-related deterioration of executive control may potentially contribute to communication difficulties in monolingual and bilingual older adults.

The remaining papers deal with pathological ageing. Recent suggestions about the protective/beneficial effects of bilingualism in Alzheimer's Disease have led to discussion of the mechanisms by which bilingualism interacts with other types of progressive neurodegeneration (Voits et al., submitted). Calabria, Pérez Pérez, Martínez-Horta, Horta-Barba, Carceller, Kulisevsky and Costa(2020) examined inhibition and cross-language interference in pre-symptomatic Huntington's Disease bilingual patients and compared them to healthy bilingual participants. Huntington's Disease primarily targets the striatum, a

structure implicated in bilingual language control and cognitive control in general, which are both affected by the bilingual experience (Pliatsikas, 2020). The authors used a cross-linguistic Stroop task in which participants named colours in the dominant or non-dominant language while the words were printed always in the dominant language, and a language switching task to test two components of bilingual language control, namely, cross-language interference and language inhibition, respectively. Only the latter component was found to be impaired in the patient group compared to the healthy one, further confirming the role of the striatum in language control in bilingualism. The lack of impairment seen for cross-language interference was interpreted as a task effect, as the participants were requested to name in one language only, and the authors speculate that the striatum might come into play when both languages are potential candidates for production.

Finally, Aveledo, Higuera, Marinis, Bose, Pliatsikas, Meldaña, Martínez-Guínés and García-Domínguez (2020) studied the executive control abilities of bilingual and monolingual Multiple Sclerosis patients and respective control groups. Multiple Sclerosis primarily targets the white matter of the brain, which has been shown to be “reinforced” by bilingualism (Pliatsikas, 2020), and may also cause deficits in general cognition, including executive control. Following suggestions that bilingual advantages in executive control are more likely to appear in tasks with high demands for monitoring the environment, e.g., in tasks with constant and unpredictable changes in trial types (Costa, Hernández, Costa-Faidella, & Sebastián-Gallés, 2009), Aveledo and colleagues used a Flanker task with two monitoring (high and low) conditions by varying the proportions of congruent and incongruent trials. Their results showed that the four groups did not differ in terms of their inhibitory control abilities, as measured by the standard Flanker effect. However, the monolingual patients were found to be significantly worse than the other three groups with respect to their overall monitoring abilities, which suggested they were experiencing a higher monitoring cost. This finding was

treated as some preliminary indication of a cognitive reserve for the bilingual patient group, even though it did not significantly differ from the control groups.

Summing up, the present Spotlight Issue serves to demonstrate that research on bilingualism and the declining brain is interesting and important, as it can have severe implications for a number of fields beyond cognitive psychology and neuroscience, including clinical neuroscience and language education; however, it is still in its infancy. We hope that this issue will inform and inspire colleagues to expand the field by conducting well-designed research on bilingual populations covering the entire spectrum of brain decline, ranging from effects of healthy ageing to severe progressive and acute neurodegeneration.

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