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Evidence against a cognitive advantage in the older bilingual population

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Abstract

Recent evidence has challenged long-standing claims that multi-language acquisition confers long-term advantages in executive function and may protect against age-related cognitive deterioration. We assessed evidence for a bilingual advantage in older monolingual and bilingual residents matched on age, gender and socioeconomic status. A comprehensive battery of tests was administered to measure non-verbal reasoning, working memory capacity, visuo-spatial memory, response inhibition, problem-solving and language proficiency. Analyses, including Bayes factors, revealed comparable performance in both groups, with no significant differences on any task (and the only trend, found for the Tower of London task performance, indicated a monolingual advantage). Overall, therefore, our findings run counter to the bilingual advantage hypothesis. We consider the implications of our study, and offer suggestions for future work in this area.

Keywords: bilingualism, executive function, working memory, ageing population, bilingual advantage, cognitive reserve, Bayesian methods.

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Introduction

Scientific advances have led to a remarkable increase in life expectancy over the past century (Christensen, Doblhammer, Rau & Vaupel, 2009), with global predictions that, by 2050, one in six of us will be aged 65 or over (WHO, 2011). Nevertheless, quality of life has not kept pace with this increase in longevity, and the burden that age-related cognitive deterioration places on affected individuals, their families, and on healthcare provision is a major societal concern. There is clearly an urgent need to develop ways for protecting and managing cognitive health in the elderly population (Brookmeyer, Johnson, Ziegler-Graham, Arrighi, 2007). Recent research has suggested that factors such as continuing physical activity and cognitive effort may help promote "successful ageing" (Reed et al., 2011; Sattler et al., 2012; Cosco et al., 2014; Ngandu et al., 2015), although the viability of activities such as 'working memory training' for offsetting the effects of neurological impairment on cognition has been questioned (for a review see von Bastian & Oberauer, 2014).

One factor claimed to potentially reduce the deleterious effects of ageing on cognition is the process of becoming bilingual (e.g., Kave et al., 2008; Bak et al., 2014; Bialystok et al., 2016). This effect is thought to be driven by the increased inhibitory, attentional and working memory demands associated with operating effectively in bilingual relative to monolingual contexts, which may, over time, promote increased cognitive capacity or 'reserve' (Adesope et al., 2010; Bialystok et al., 2004; Salvatierra & Rosselli, 2011). Early evidence for the enhancement of cognitive reserve (CR) associated with bilingualism stems from retrospective age-of-diagnosis comparisons among bilingual and monolingual patient populations, with the latter reported to receive clinical diagnosis (typically of Alzheimer's disease) approximately 4 years earlier (Bialystok et al., 2007; Craik et al., 2010; Schweizer et al., 2012). Other research indicates that this protective

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effect may only operate in particular sections of society, such as immigrant groups (Chertkow et al., 2010) or those who had received poor or limited education (Gollan et al., 2011). More recently, however, Alladi et al. (2013) published a large-scale study of over 600 patients in India indicating that bilingualism may substantially delay the onset of a range of dementia types, irrespective of immigration status and education (see also Woumans et al., 2015). These reports of positive effects, however, are balanced by others producing null or inconsistent findings (e.g., Crane et al., 2010; Sanders et al., 2012; Lawton et al., 2015; for a review see Calvo et al., 2015).

In addition to observations of cognitive benefits associated with bilingualism, there have also been reports of neurological effects. For example, Luk et al. (2011) provide evidence for less deterioration of white matter integrity and better anterior/posterior functional connectivity in older bilinguals relative to age-matched monolinguals. Similarly, increased tissue density in cortical areas associated with cognitive control/conflict monitoring have been reported in older bilingual (relative to monolingual) participants (e.g., Abutalebi et al., 2012, 2013, 2014, 2015; Zou et al., 2012). Conversely, in bilingual Alzheimer patients with significant structural degeneration there is some evidence for relatively preserved cognitive function, consistent with bilingualism offering protection against progression of cortical atrophy (Schweizer et al., 2012; Gold et al., 2013; Perani et al., 2017). The extent to which such findings may, at least in part, be explained by systematic group differences on extraneous or inadequately controlled covariates, however, remains an issue of ongoing debate (e.g., Kousaie and Phillips, 2012).

Over the past decade, the bilingual advantage has been increasingly challenged, with a large number of studies failing to support it (e.g., Morton & Harper, 2007; Paap & Greenberg, 2013; Kirk et al., 2014; de Bruin, Treccani, & Della Sala, 2015; Anton et al.,

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2016). These findings have been further supported by neuroimaging studies, which were also unsuccessful in the identification of a behavioural bilingual advantage despite evidence for different patterns of functional connectivity and/or levels of task-specific activity (Ansaldo, Ghazi-Saidi & Androver-Roig, 2015; Grady, Luk, Craik & Bialystok, 2015; Berroir, Ghazi-Saidi, Dash, Androver-Roig, Benali, Ansaldo, 2017). Even when attempts have been made to carefully isolate various mechanisms associated with higher level cognitive control, comparable bilingual and monolingual performance on all measures has been reported (e.g., Dunabeitia, Hernandez, Anton, Macizo, Estevez, Fuentes, & Carreiras, 2014; Paap, Johnson, & Sawi, 2014). Overall, evidence for a bilingual advantage in conflict resolution (the central theoretical claim) is sporadic and sensible control for important potentially confounding covariates has been inconsistently applied (for reviews see Hilchey & Klein, 2011; Kousaie & Phillips, 2012; Paap et al., 2014). Furthermore, publication bias towards significant findings is an additional issue (de Bruin et al., 2015).

To date, the majority of studies supporting a bilingual advantage have employed a single test of inhibitory control, typically the Simon, Flanker or Stroop task. More specifically, the Simon task measures stimulus-response compatibility effects (Simon, 1969), the Flanker measures the effects of dimensional overlap between an irrelevant and a relevant stimulus (Eriksen & Eriksen, 1974) and the Stroop task measures effects of response conflict due to automatic processing of a task irrelevant stimulus feature (Stroop, 1935). More recently, however, studies have reported results from a wider range of tasks. For example, Kerrigan, Thomas, Bright and Filippi (2016) employed the change blindness task (Rensink, 2002) to investigate visuo-spatial working memory in age-matched monolingual and bilingual adults. They found that bilingual speakers were significantly faster and more accurate than monolinguals at detecting visual changes.

DOI: 10.1177/1747021818796475

Paap & Sawi (2014) systematically compared bilinguals and monolingual university students on 13 different indices of executive function (derived from performance on four tasks). Although the bilinguals numerically outperformed monolinguals on six of the indices, none of these reached conventional significance. Conversely, monolinguals significantly outperformed bilinguals on three indices (including the Simon effect).

Against this debate about the existence, nature and strength of a bilingual cognitive advantage, the present study address performance in older adults, employing a broad range of tasks. English speaking monolingual adults were matched with bilinguals of different linguistic backgrounds with respect to age, gender and socio-economic status (SES). The participants were assessed on typical tasks used in the literature as well as on tasks assessing verbal short-term and working memory, reasoning, problem solving and intelligence and visuo-spatial working memory. The latter task was employed to further explore the bilingual advantage demonstrated by Kerrigan et al. (2016). Given the current vigorous debate about the source of reported bilingual advantages, and challenges to its existence, we did not construct predictions about size or directionality of effects. Instead we elected to subject our data both to standard null hypothesis testing and to the Bayesian approach in which the data are considered under both null and alternative hypotheses.

Methods

Participants

Participants were recruited through the University of the Third Age (U3A) in London and via additional opportunity sampling. Seventy-four healthy retired individuals were tested: 37 English monolinguals (male = 16, female = 21; M = 69.4 years old, SD = 4.3) and 37

DOI: 10.1177/1747021818796475

bilinguals (male = 18, female = 19; M = 70.6 years old, SD = 4.6), matched on age ($t(72) = -1.21$, $p = .23$).

Participants were selected according to their health status and age range. More specifically, all participants were healthy (no history of neurological or neuropsychological disorders) and between 60 and 80 years of age. The health information collected showed that some participants received medication for blood pressure or statins. These participants were deemed to be suitable as blood pressure medications have been shown to prevent cognitive decline caused by blood pressure imbalances (Novak & Hajjar, 2010) and therefore they do not impair cognitive functioning. Similarly, statins have been previously associated with cognitive impairment, although a recent review of randomized clinical trials revealed no association between statin therapy and cognitive impairment (Ott, Daiello, Dahabreh, Springate, Bixby, Murali, et al., 2015).

All participants completed a questionnaire providing biographical and linguistic information (Filippi et al., 2012; Filippi, Karaminis, & Thomas, 2015). Bilingual participants were highly proficient in both languages and reported their use in everyday life for over 50 years. Fifteen of them reported to know a third language and two participants reported to know a fourth (see Table 1). All monolingual participants were native English speakers with little or no exposure to a second language. All participants self-declared normal or corrected-to-normal vision and hearing.

With regard to language experience, bilingual participants reported they currently used English more (M = 89%) than their other language (M = 11%) on a daily basis and, on average, they had been exposed to their second language for 56 years. Eighteen bilingual participants reported to switch between languages in every day life.

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In addition to age, the participants were matched on SES, measured via educational level and previous occupation. The educational level was scored from 0-6, with 0 representing the lowest (high school diploma) and 6 the highest (Doctorate/PhD) qualification. The occupational status was scored using the Standardized Occupational Classification 2010 (Office of National Statistics, 2010). An independent *t*-test performed on SES scores revealed that bilinguals and monolinguals had similar educational and occupational statuses ($t(72) = -1.59$, $p = .12$; , $t(72) = .17$, $p = .87$, respectively). Twelve bilingual participants moved to the UK later in life for professional and/or educational reasons.

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ADD TABLE 1 ABOUT HERE

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Materials and Procedure

Participants were individually tested in a quiet room at the Institute of Education (UCL), or in their own home, with the duration of each session averaging one hour.

After completing the background questionnaires (Filippi et al., 2012, 2015), all participants performed a battery of six tasks. These tasks measured vocabulary knowledge in the English language (British Picture Vocabulary Scale III), non-verbal reasoning (Raven's Advanced Progressive Matrices), executive function (Simon Task), planning and problem solving (Tower of London), verbal working memory (Digit Span forwards and backwards) and visuo-spatial working memory (Change Blindness).[1]

Each task was accompanied with detailed instructions in English and participants were given the opportunity to ask any questions prior to beginning the task. The Simon task

[1] For technical reasons, the change blindness task was administered only to a subset of the whole sample, N=26 monolinguals and N=22 bilinguals.

DOI: 10.1177/1747021818796475

and the Tower of London were carried out on a Dell XPS 12, with 12.5-inch widescreen display and 1920 x 1080 pixels resolution.

Simon task

The design and procedure of this task was adapted from Prinz and Hommel (2002) and programmed in E-prime 2.0 [Schneider, Eschman & Zuccolotto, 2002]. Responses were recorded via a gamepad controller (Logitech F310 PC USB).

This task comprised of 36 trials. Each trial was initiated with the presentation of a fixation point (+) at the centre of the screen for 500ms. The fixation point was followed by the target stimulus which was either a filled blue or red star (height = 1.7cm, width = 1.8cm on screen) displayed 3.9° to the left or right of the fixation point (Figure 3). The left index finger was rested on the left key "LB" (assigned for the red star) and the right index finger rested on the right key "RB" (assigned for the blue star) of the controller. The goal was to press the corresponding key as quickly as possible according to the colour of the displayed star which was presented on the screen for 1 second. During this task, a congruent trial was defined by the position of the star and the corresponding key being on the same side, while an incongruent trial involved the star and key being on opposite sides. Participants scored one point when they had correctly pressed the corresponding key. Failure to respond within the allocated time within the trial was classified as an error. Reaction time (milliseconds) and accuracy (correct/incorrect) were automatically recorded by the software. Reaction time was based only on correct responses.

Tower of London

The design and procedure of this task was adopted from Shallice (1982). The 12-trial version, available as part of the open source PEBL battery [http://pebl.sourceforge.net/], was employed. Each trial comprised of two figures, one above the other. The top figure

DOI: 10.1177/1747021818796475

contained three columns of disks or 'stacks' (the target configuration), with a figure directly below containing the same disks but in a different arrangement across the three columns (the starting configuration). In this version of the task, all problems had three disks (red, green, blue). To solve the trial, participants were required to move the discs from the lower, starting configuration to match the top configuration (using the mouse) as quickly but efficiently as possible (i.e., in the smallest number of moves). Constraints were that (a) there were a defined number of permitted moves to solution (ranging from 2 to 5), (b) participants could move only one disk at a time and (c) a limit was set on the possible height of each stack of disks. A trial was successfully completed if the solution was reached within these applied constraints. Reaction time (RT) in milliseconds was automatically recorded by the software at the point of pressing the right click of the mouse (first move RT) and at the end of all the trials (total RT). The first move RT provided an indication of initial planning/preparation time prior to executing the solution. The total RT indicated the time the required to complete the whole task.

Change Blindness

The design and procedure of this task was adapted from Kerrigan et al. (2016). Eighteen trials of everyday life scenes were presented to participants on the computer screen, each alternating at a rate of 250ms between an original and slightly modified version. Following each trial a black screen was presented for 1000ms. These alternations lasted for 1 minute. The aim of this task was “to spot the difference” by identifying one element that was different between the images. The difference could involve colour, spatial location or presence/absence of an object. Once identified, the space bar was pressed and the participants called out the difference. The experimenter recorded the responses and the software automatically recorded the RT and accuracy. Participants were first presented with three example images, followed by 18 test trials.

DOI: 10.1177/1747021818796475

British Picture Vocabulary Scale III (BPVS III)

We employed Dunn and Dunn's (1997) version of this test of receptive vocabulary, with 14 sets of 12 slides. On each slide four pictures (one target and three foils) were presented simultaneously. The experimenter said a word corresponding to only one target picture. The participants were required to select the target.

All participants started from set 10, designated as suitable from the age of 14. Participants proceeded to the next set only if all items were correctly identified. If participants produced one or more errors in set 10, set 9 was instead presented. This rule was applied until all items in a set were correctly identified. The task was discontinued if a participant failed to correctly select 8 or more of the 12 target items in a given set. The ability score was computed by subtracting the number of errors from the highest possible score.

Raven's Progressive Matrices Task

This procedure employed the materials designed by Raven, Raven and Court (1998), comprising 12 increasingly complex trials in which participants were required to select the missing piece from a geometric design, given 8 possible choices (an example is provided in Figure 2). The test was originally designed to assess abstract reasoning, and is widely employed as a measure of fluid intelligence. It is untimed, with participants typically completing it within 5 minutes.

Digit Span Forward and Backward

This task contributes to the working memory index of Wechsler Adult Intelligence Scale (Wechsler, 2008). Participants were instructed to listen to a sequence of numerical digits. The aim was to repeat the sequence verbatim (forward) and in reverse order (backward) as instructed by the researcher. At the start, participants were presented with two trials of 2 digits in the forward condition. If at least one of these two sequences were repeated

DOI: 10.1177/1747021818796475

correctly, two trials of N+1 digits were presented (with this process repeated up to the maximum of 9 digits). If both trials of a given digit length were failed, the condition was discontinued. The backward digit span was then administered using the same rules. Scores were recorded as total number of trials correct for both conditions.

Design

This study consisted of a matched-pairs mixed design, where the participants were matched according to gender, age, language group (monolinguals vs. bilinguals) and SES (education and occupation). All participants completed the full test battery.

Results

Analyses of background measures

Both groups performed comparatively on measures of non-verbal reasoning (Raven's matrices), $t(72) = .27$, $p = .79$, fluency in the English language (BPVS), $t(72) = 1.59$, $p = .12$ and working memory (Digit Span forward: $t(72) = .38$, $p = .70$, and backward: $t(72) = .15$, $p = .88$).

These data suggest that any differences obtained from the main experimental tasks are unlikely to be attributable to group differences in general cognitive functioning and SES. Table 2 summarises the results of these analyses.

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DOI: 10.1177/1747021818796475

Effect of language group on Executive Functioning Tasks

For the Simon task, a 2x2 mixed ANOVA with *Group* as the between-subject factor (Monolinguals/Bilinguals) and *Congruency* as the within-subject factor (Congruent/Incongruent trials) was carried out on accuracy and on RT for correct responses (Table 3).

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For RT the main effect of *Group* on RT was not significant, $F(1,72) = 1.18$, $p = .28$, $\eta_p^2 = .02$, but there was a significant main effect of *Congruency*, $F(1,72) = 136.66$, $p < .001$, $\eta_p^2 = .66$, indicating faster performance on congruent trials (Monolinguals: M = 537ms, SD = 77.5; Bilinguals: M = 533ms, SD = 83.5), than incongruent trials, (Monolinguals: M = 608ms; SD = 74.0; Bilinguals: M = 620ms; SD = 83.0). There was a non-significant interaction between *Group* and *Congruency*, $F(1,72) = .39$, $p = .54$, $\eta_p^2 = .01$, indicating similar patterns of response time performance in monolinguals and bilinguals.

The data were also examined by estimating a Bayes factor (null/alternative). The analysis suggested that for *Group* the data were 0.45:1 in favour of the null hypothesis, but for *Congruency* the data were highly in favour of the alternative hypothesis,

DOI: 10.1177/1747021818796475

(BF_{10}=1.450e+15), Additionally, confirming the results of the ANOVA, there was substantial evidence against the interaction *Congruency * Group effect* (BF_{01} =0.26).

For accuracy, the main effect of *Group* was not significant, $F(1,72) = .62$, $p = .43$, $\eta_p^2 = .97$. Nevertheless, there was a significant main effect of Congruency, $F(1,72) = 21.50$, $p < .001$, $\eta_p^2 = .23$, revealing better accuracy on congruent trials. The *Group* x *Congruency* effect was non-significant, $F(1,72) =.29$, $p = .59$, $\eta_p^2 = .01$, indicating similar patterns of accuracy performance in monolinguals and bilinguals.

Bayes factors for accuracy were also in favour of the null hypothesis for *Group* (BF_{01} =0.27) *but confirmed to be more likely in favour of the alternative hypothesis for Congruency* (BF_{01} =3.61) *and offered substantial evidence against the interaction Congruency * Group effect* (BF_{01} =0.27).

For the Tower of London task an independent *t*-test revealed statistically equivalent group performance on correct trial completions, $t(72) = 1.58$, $p = .12$.

Despite similar level of accuracy, monolinguals were on average 6 seconds faster than bilinguals in deciding the first move, and 8 seconds faster in completing the trial.

Further independent *t*-tests on response times revealed statistical trends for first move RT ($t(72) = -1.10$, $p = .051$) and trial completion times ($t(72) = -1.73$, $p = .09$) between the groups (see Table 4).

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Bayesian independent *t*-tests suggested that the data were 1.43 and 1.16 times more likely in favour of the null hypothesis for accuracy and trial completion time. However, there

DOI: 10.1177/1747021818796475

was substantial evidence for the alternative hypothesis for first move RT *(BF_{10} =1.29)*, or rather, that monolinguals were faster than bilinguals in deciding the first move.

Visuo-spatial skills in the elderly population

On the Change Blindness task, an independent *t*-test performed on a subset of the sample (N=26 monolinguals and N=22 bilinguals) revealed that no significant effects for accuracy, $t(46) = -.33$, $p = .74$, or RT, $t(46) = -.48$, $p = .63$, indicating comparable visuo-spatial memory abilities in the monolingual and bilingual groups.(Table 5).

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Bayes factors suggested that the data were 3.32 and 3.16 times in favour of the null hypothesis for both accuracy and RT.

The role of second language age of acquisition

Individual differences analyses were conducted within the bilingual group to establish whether age of second language acquisition could reliably predict any cognitive effect on the experimental measures.

Linear regression indicated that an earlier age of second language acquisition was a significant predictor of best accuracy with incongruent trials in the Simon task (r = -.368, $p = .025$), but not for any of the other measures.

DOI: 10.1177/1747021818796475

Discussion

The primary rationale for this study was to assess the viability of claims that bilingualism confers a cognitive advantage in older age and, therefore, to contribute to the current debate about the possible protective effects of multi-language acquisition against age-related cognitive deterioration. In order to address these issues, older bilinguals were compared with native age-matched English monolingual speakers on a series of cognitive tasks. The measures used included non-verbal abstract reasoning, working memory, visuo-spatial working memory, inhibition, planning and problem solving tasks.

Across our tasks, and using both traditional statistics and Bayesian methods, the only evidence for a group difference indicated a trend towards a bilingual *disadvantage* in response times in the Tower of London task (i.e., bilingual participants took longer to respond despite eliciting statistically equivalent accuracy performance to monolinguals). These findings therefore run counter to the argument that bilingualism offers cognitive advantage throughout the lifespan and/or protection from ageing effects (e.g., Bialystok et al., 2004; Bak et al., 2014) and are more consistent with claims that the proposed bilingual advantage might be better explained by systematic group differences on demographic/background variables such as socioeconomic status (e.g., Goldsmith & Morton, 2018; Morton & Harper, 2007).

Within the bilingual group, age of acquisition was a reliable predictor of best accuracy in the Simon task, only for more challenging, incongruent trials. This is in line with previous findings indicating that age of second language exposure/acquisition might be relevant to

DOI: 10.1177/1747021818796475

inhibitory control (e.g., Filippi et al., 2012). Nevertheless, this effect did not translate to an overall bilingual advantage in accuracy performance.

Much of the evidence base for the bilingual advantage has been based on the Simon task, but the findings have lacked consistency. For example, Bialystok, Craik and Luk, (2008) demonstrated a bilingual inhibitory advantage in an older sample (Mean age = 68), but this appeared to be driven by overall performance rather than specifically by an advantage on the trials requiring inhibition (which would be predicted by the bilingual advantage theory as originally proposed). Other studies, however, have supported a *monolingual* advantage on this task. For example, Salvatierra and Rosselli (2011) reported a significant monolingual advantage in congruent trials of the Simon task, and Schroeder and Marian (2012) also report a numeric (but not significant) advantage in this condition. In another study, Billig and Scholl (2011) reported that monolinguals elicited longer response times on congruent trials but were faster overall over the two conditions as well as being more accurate than bilinguals. Paap and colleagues have also had mixed results on the Simon task, either reporting a null effect (Paap & Greenberg, 2013) or, surprisingly, a significant monolingual advantage (Paap & Greenberg, 2013; Paap & Sawi, 2014). In response, some authors have argued that the Simon task is not sufficiently sensitive to reliably detect a bilingual advantage in executive function (e.g., Costa et al., 2009; Kousaie, Sheppard, Lemieux, Monetta & Taler, 2014), but this claim cannot easily be reconciled with the evidence base for the bilingual advantage hypothesis, much of which derives from observations of Simon task performance (for a review see Filippi, D'Souza & Bright, 2018).

Results from the change blindness task revealed no statistically significant differences in accuracy or response time between the two groups. This observation, therefore, does not support an earlier report indicating a bilingual advantage in visuo-spatial memory in

DOI: 10.1177/1747021818796475

young adults (Kerrigan et al., 2016). Given that this study employed older participant groups, further investigations should consider and explore whether possible bilingual effects in visuo-spatial processing are present at earlier stages of life and attenuate (or disappear) in later life.

Our findings add to the weight of evidence against the claim that bilingualism offers protection against the effects of ageing on cognition, and that there is a straightforward cognitive advantage associated with multi-language acquisition more generally. However, the contradictions in the field remain difficult to reconcile. We welcome the drive towards acknowledgement and better experimental control of potential biases and confounds in the field (e.g., Hilchey & Klein, 2011; Paap, Johnson, & Sawi, 2015; Kousaie & Phillips, 2017) and encourage further development of theoretical models. Given the difficulty in ensuring like-for-like comparisons across bilingual and monolingual groups, such that the range of possible alternative explanatory variables is adequately-controlled, the level of dispute in the field is perhaps unsurprising. There are also likely to be different, dynamically interacting covariates operating across stages of development from childhood through to the final years of life. In our view, carefully controlled developmental work is needed in order to clarify specific mechanisms responsible for observed bilingual cognitive advantages, and we must recognize that the balance of cognitive control mechanisms operating towards the later stages of life may not be the same as that operating at other stages of life – and this has potential implications for whether - and the extent to which - there is an operational bilingual cognitive advantage.

For the present study we controlled for a range of possible confounding covariates, including socioeconomic status, frequently highlighted as particularly problematic in this field of study (e.g., Antón et al., 2014; Morton & Harper, 2007; Mueller-Gathercole et al.,

DOI: 10.1177/1747021818796475

2010). However, there were some study limitations. The mean acquisition of the second language in our bilingual group was 15 years old, raising the possibility that a multi-lingual environment during infancy and early childhood is crucial for offsetting cognitive deterioration in later life. However, recent research has indicated that second language acquisition later in life is likely to 'exercise' inhibitory control mechanisms more substantially than when both languages are experienced from birth (Bak et al., 2014; Tao, Marzecova, Taft, Asanowicz, & Wodniecka, 2011). Our sample also primarily employed English (89% of the time) rather than the second/other language, and it is possible that more balanced day-to-day use of two or more languages might be associated with a different pattern of findings. Moreover, only 46% of the bilingual participants reported regularly switching between two languages (i.e., using both languages within or between sentences) and 37% of the participants stated that they regularly substitute words from one language with those from another. Perhaps switching between languages and substituting words might have a greater impact on cognitive abilities due to the constant effort required to communicate, or it might have the reverse effect as bilinguals might use this method to reduce the cognitive strain produced by the effort to speak in their non-native language. Further work should compare evidence for a bilingual advantage between bilinguals who switch and do not switch languages during their everyday life.

To conclude, we suspect that publication bias against reporting null results is particularly problematic in the evidence base on the bilingual advantage, and we offer the present null findings as a cautionary note against recent reports that bilingualism protects against age-related cognitive (and neurological) deterioration. In our study, in which we controlled for a range of potential confounding covariates, we found no reliable evidence to support the possibility that being bilingual or multilingual compensates for cognitive decline in later life.

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Table 1. *Bilingual participants' language information.*

Linguistic Background	(in addition to English)	Bengali (n = 1) Bulgarian (n = 1) Burmese (n = 1) Arabic (n = 1) German (n = 2) Greek (n = 2) Hungarian (n = 1) Norwegian (n = 2) Polish (n = 1) Russian (n = 1) Chinese (n = 1) French (n = 17) Italian (n = 3) Spanish (n = 3)
	Third language	French (n = 5) German (n = 2) Greek (n = 1) Italian (n = 2) Spanish (n = 3) Portuguese (n = 1) Vietnamese (n = 1)
	Fourth language	Spanish (n = 1) German (n = 1)
Other linguistic background information	Age of acquisition	M = 15.03; SD = 14.8
	Switch languages*	Yes = 18; No = 19
	Substitute words**	Yes = 14; No = 23
	English usage (%)	89%
	No usage of L2 (%)	16%

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Table 2. *Descriptive statistics (mean and standard deviation – SD) for control measure of monolingual and bilingual participants. Non-verbal reasoning maximum score that could be obtained is equal to 12. Working memory maximum score that could be obtained is equal to 30. Language proficiency maximum score that could be obtained is equal to 168.*

	Monolinguals		Bilinguals	
	Mean	SD	Mean	SD
Age	69.4	4.3	70.6	4.6
Non-verbal Reasoning	8.2	2.4	8.0	2.8
Working Memory	19.6	4.6	19.2	4.6
Language proficiency	166.7	1.6	165.3	5.1
Education	3.7	1.1	4.1	0.9
Occupation	2.0	1.06	2.0	1.02

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Table 3. *Reaction times and percent correct responses in the Simon task for congruent and incongruent trials. Standard deviations in brackets.*

	Monolinguals		Bilinguals	
	RT	CR	RT	CR
Simon Task Congruent Trials	537 (77.5)	96% (.07)	553 (83.5)	94% (.07)
Simon Task Incongruent Trials	608 (74.0)	90% (.09)	620 (83.0)	90% (.08)

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Table 4. Mean r*eaction times (in seconds) and percent correct responses in the Tower of London task. Standard deviations in brackets.*

	Monolinguals		Bilinguals	
RT first move	21	(9.5)	27	(17)
RT Trial completion	32	(17)	40	(20)
Accuracy	74%	(.17)	68%	(.20)

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Table 5. Mean r*eaction times (in seconds) and percent correct responses in the Change Blindness task. Standard deviations in brackets.*

	Monolinguals		Bilinguals	
RT	12	(5)	13	(4)
Accuracy	87%	(.12)	88%	(.06)

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