Executive control in older Welsh monolinguals and bilinguals

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Abstract

Evidence for a bilingual advantage in executive control has led to the suggestion that being bilingual might protect against late-life cognitive decline. We assessed the performance of socially homogeneous groups of older (≥ 60 years) bilingual Welsh/English (n = 50) and monolingual English (n = 49) speakers on a range of executive control tasks yielding 17 indices for comparison. Effect sizes (> .2) favoured monolinguals on 10 indices, with negligible differences observed on the remaining 7 indices. Univariate analyses indicated that monolinguals performed significantly better on two of 17 indices. Multivariate analysis indicated no significant overall differences between the two groups in performance on executive tasks. Older Welsh bilinguals do not show a bilingual advantage in executive control, and where differences are observed, these tend to favour monolinguals. A possible explanation may lie in the nature of the sociolinguistic context and its influence on cognitive processing in the bilingual group.

Keywords

Cognitive aging

Cognitive reserve

Inhibition

Response conflict

Working memory

With increasing longevity and an expanding older population, identification of factors that can help to maintain cognitive health and reduce cognitive decline in later life is vitally important. It has been argued that a range of psychosocial factors, including lifelong level of cognitive, social and physical activity and size and complexity of social networks, may slow the development or reduce the impact of cognitive decline in later life (Williams, Plassman, Burke, Holsinger, & Benjamin, 2010). Under the cognitive reserve hypothesis (Stern et al., 2003), engagement in complex mental activity over the lifespan, reflecting an active cognitive lifestyle, builds a capacity that helps to maintain cognitive function in older age (Valenzuela & Sachdev, 2006), although it has also been suggested that those with more resilient brains may engage in more complex mental activity (Salthouse, 2006). A decline in frontally-mediated executive function due to changes in fronto-striatal circuits is a core component of the cognitive changes seen in healthy ageing (Buckner, 2004; Craik & Bialystok, 2006a). Executive function has been variously defined, conceptualised and measured (Hankee et al., 2013; Martyr & Clare, 2012; Royall, 1994; Salthouse, 2005), but it is generally acknowledged that the broad construct of executive function fractionates into a number of specific abilities. Recent research on executive function has focused in particular on the related but separable domains of inhibition and management of response conflict, set-shifting and updating of working memory (Miyake & Friedman, 2012), although other domains such as mental flexibility, dual-task performance and planning are also important. Together these domains can be understood in terms of executive control processes, 'the set of fluid operations that enable intentional processing and adaptive cognitive performance' (Craik & Bialystok, 2006a, p. 131). These processes include the ability to selectively attend to important aspects of a problem, inhibit attention to irrelevant or unhelpful information, and switch readily between possible alternative options or responses.

Recent evidence for a bilingual advantage in executive control processes (Bialystok, 2011) has led to the suggestion that being bilingual might contribute to increased cognitive reserve (Bialystok, Craik, & Luk, 2012), and learning a second language to a high standard may have a protective effect on cognitive function in later life (Bak, Nissan, Allerhand, & Deary, 2014). The verbal skills of bilinguals in each of their languages are often weaker than the skills of monolinguals in each language, and bilinguals typically achieve poorer scores on vocabulary, naming and fluency tasks (Bialystok, Craik, & Luk, 2008; Bialystok et al., 2012; Gollan, Fennema-Notestine, Montoya, & Jernigan, 2007). In contrast, however, several studies have shown that bilinguals outperform monolinguals on non-linguistic tasks involving response conflict or the need to inhibit a learned or habitual response, such as Simon, spatial Stroop or flanker (Bialystok, 2006; Costa, Hernandez, & Sebastian-Galles, 2008) tasks. On these tasks, bilinguals show smaller differences in reaction time between congruent and incongruent trials, indicative of a lower interference effect. A recent comprehensive review (Hilchey & Klein, 2011) indicated that this interference effect was initially thought to result from an inhibitory control advantage resulting from practice in switching between two languages given that both languages of a bilingual are active continuously (Bialystok, 2011). The inhibitory control hypothesis was, however, called into question by the observation that, where the bilingual advantage is observed, bilinguals usually outperform monolinguals on both congruent and incongruent trials. This finding suggests that bilinguals have a more general advantage in executive processing, resulting in faster reaction times in tasks entailing some degree of response conflict (Bialystok, 2006; Costa, Hernandez, Costa-Faidella, & Sebastian-Galles, 2009; Hilchey & Klein, 2011). Therefore, the current view is that this bilingual advantage arises because the general executive control system is involved in language processing in order to deal with the conflict presented by joint activation of the two languages. The extra practice gained in dealing with such conflict means that the executive control system becomes more efficient in monitoring through attending to and addressing situations requiring selection or conflict resolution (Bialystok, 2011; Costa et al., 2009; Gollan, Sandoval, & Salmon, 2011; Hilchey & Klein, 2011; Weissberger, Wierenga, Bondi, & Gollan, 2012). A recent systematic review focusing on studies conducted with children reported that bilingualism confers benefits in a range of domains, including attentional control, working memory, metalinguistic awareness, and abstract and symbolic representation skills (Adesope, Lavin, Thompson, & Ungerleider, 2010). A global bilingual executive processing advantage could translate into greater cognitive reserve for bilingual individuals (Bialystok et al., 2012; Gold, 2015), providing increased protection against the effects of age-related brain pathology (Alladi et al., 2013; Bialystok, Craik, & Freedman, 2007). Recent evidence from neuroimaging studies supports the view that lifelong bilingualism mitigates age-related decline in cognitive control processes (Gold, Kim, Johnson, Kryscio, & Smith, 2013) and suggests that this results from better maintenance of white matter integrity and functional connectivity (Luk, Bialystok, Craik, & Grady, 2011).

It has been suggested that, while the global advantage can be detected across the lifespan, the interference effect is more evident in later life (Bialystok, Craik, Klein, & Viswanathan, 2004). Several studies with adults aged over 60 have yielded evidence for both the global advantage (Bialystok et al., 2004; Bialystok, Martin, & Viswanathan, 2005; Emmorey, Luk, Pyers, & Bialystok, 2008) and the interference effect (Bialystok et al., 2004; Bialystok et al., 2005; Emmorey et al., 2008). A bilingual advantage is not always found, however, neither in children nor in young adults (e.g. Duñabeitia et al., 2014; Kousaie, Sheppard, Lemieux, Monetta, & Taler, 2014; Paap & Greenberg, 2013), nor in the older age group where effects appear most robust (Kousaie & Phillips, 2012; Kousaie et al., 2014). In addition, where the advantage is shown in experimental tasks, some studies have suggested that it diminishes with practice (Costa et al., 2009; Costa et al., 2008). Therefore, further investigation of this phenomenon is warranted. It is important to note that the bilingual advantage in older people, where detected, has been demonstrated on a relatively limited set of tasks, and it has been suggested that observed effects may be task-specific rather than reflecting efficacy of general executive functioning (Paap, Johnson, & Sawi, 2015). If there is a general advantage in executive processing contributing to cognitive reserve, then bilinguals should show better performance than monolinguals on a broad range of tasks for which executive control is important (Hilchey & Klein, 2011). In partial support of this, in one study older bilinguals performed better than monolinguals in planning, time allocation and task-switching on an ecologically-valid 'simulated cooking breakfast' task (Craik & Bialystok, 2006b). There is a need therefore to examine performance on a wider range of tasks (Paap et al., 2015), and this is a primary aim of the present study.

This study will examine the performance of older Welsh/English bilinguals and English-speaking monolinguals on a broad range of tasks for which executive control is important, with the aim of identifying the cognitive profiles of the two groups across key domains of executive function and outlining the implications for cognitive reserve. The importance of controlling for possible confounding factors, such as immigration and other relevant demographic variables, in comparisons of monolingual and bilingual performance has frequently been emphasised. This is addressed as fully as possible in this study by recruiting from a socially and culturally homogenous community in North Wales, United Kingdom, by controlling for socio-economic status and educational level if differences between the groups are observed, and by further examining bilingual performance in relation to the degree of use of the two languages in the bilingual group.

Method

Design

This cross-sectional cohort study compared healthy older Welsh/English bilingual and monolingual English-speaking participants utilising experimental tasks, standardised neuropsychological tests and questionnaires. This investigation was part of the Bilingualism as a protective factor in Age-related Neurodegenerative Conditions (BANC) study (Clare et al., 2014; Hindle et al., 2015), which examined the effects of bilingualism in people with Alzheimer's disease and Parkinson's disease, and in healthy older people. The study protocol was approved by the relevant University and National Health Service ethics committees.

Participants

Participants were recruited in North Wales, United Kingdom. Wales is an officially bilingual constituent nation of the United Kingdom, with a population of 3.1 million, of whom 96% are white British and 19% speak Welsh as well as English (Office for National Statistics, 2011; Welsh Government, 2012). The counties of North Wales tend to have above average proportions of Welsh speakers, with the highest proportions in western areas: prevalence is 63% in Anglesey, 65% in Gwynedd, 35% in Conwy, 31% in Denbighshire, 17% in Flintshire and 18% in Wrexham (Office for National Statistics, 2011; Welsh Government, 2012).

The participants were 99 individuals aged 60 or over, 49 monolingual and 50 bilingual. 'Bilingual' was defined as speaking both English and Welsh for all or most of one's life and being fluent in both languages, but not in any additional languages. 'Monolingual' was defined as speaking English for all of one's life and being fluent in English, but not in any other language. To rule out the presence of cognitive impairment, participants had to score 26 or above on the Mini-Mental State Examination (MMSE; Folstein, Folstein, & McHugh, 1975) to be included in the study. Participants were recruited through articles in English language newspapers, local Welsh-language newsletters and presentations to community groups. The majority of participants were drawn from the North Wales counties of Anglesey (40), Gwynedd (37), Conwy (12) and Denbighshire (5), with the remaining 5 coming from other areas. North Wales is a predominantly rural area, and participants, whether monolingual or bilingual, mostly lived in small towns, villages or semi-rural locations.

Language status was assessed with the Language Questionnaire - short version (Gathercole & Thomas, 2009). Responses indicated that the bilingual group had mostly grown up in Welsh-speaking homes; 47 (94%) had spoken Welsh from birth or before starting school, 40 (83%) said their mother had always spoken to them in Welsh, and 42 (88%) said their father had always spoken to them in Welsh. A smaller proportion had spoken English from birth or before starting school (15; 31%), beginning to speak Welsh on starting school or during their primary education. On average they currently spoke Welsh about two-thirds of the time and English about one-third of the time. They were confident users of both languages, giving median scores of 5 on a 1 - 5 scale (where 1 is low and 5 is high) for ability to speak, understand, read and write in both Welsh and English. Thus, the bilingual group could be characterised as consisting of simultaneous or early sequential bilinguals.

None of the monolinguals reported use of any language other than English in their daily lives. Twenty-four monolinguals (49%) and 18 bilinguals (37%) indicated that they had some experience of learning a language other than English or Welsh; in most cases this consisted of being taught French in secondary school, acquiring some German during army service, or attending evening classes to learn holiday Spanish. In addition, in the monolingual group, 25 individuals (51%) indicated that they had engaged to a limited extent with learning the Welsh language at some time in the past. This occurred during secondary schooling for 4 people and in younger adulthood for 15 people; non-Welsh speaking adults, some of whom will have moved from other areas of the United Kingdom, are encouraged to try to learn some basic Welsh, with language classes widely available. Engagement with Welsh had occurred during primary education for 3 people, and earlier for 3 people who encountered some Welsh in the home environment at a young age; however, these 6 individuals, due to changes in circumstances, had subsequently not developed their Welsh language skills further and did not consider themselves to be Welsh speakers.

Measures

Background measures

Information on age, gender, education and socio-economic status was collected. Health status was assessed with the EQ-5D visual analogue scale (The EuroQol Group, 1990), functional ability with the Instrumental Activities of Daily Living scale (Lawton & Brody, 1969), mood with the Hospital Anxiety and Depression Scale (Snaith & Zigmond, 1994), irregular word reading in English with the National Adult Reading Test-Revised (Nelson & Willison, 1991), and cognitive status with the MMSE. The Lifetime of Experiences Questionnaire (scored according to Valenzuela & Sachdev, 2007, with sample-derived weightings) provided a cognitive lifestyle score incorporating information about education, occupation and engagement in cognitive, physical and social activity throughout the lifespan, which served as a proxy measure of cognitive reserve.

Tests of language ability

English language proficiency was assessed with the 15-item version of the Boston Naming Test (Kaplan, Goodglass, & Weintraub, 1983), Spot-the-Word Test (Baddeley, Emslie, & Nimmo-Smith, 1992; Baddeley, Emslie, & Nimmo-Smith, 1993), and British Picture Vocabulary Scale (Dunn, Dunn, & Styles, 2009). Bilinguals additionally completed the Prawf Geirfa Cymraeg i Oedolion (Welsh Vocabulary Test for Adults; Gathercole & Thomas, 2009), and responded to the Boston Naming Test in Welsh.

Tests of executive function

Four domains of executive function were assessed, using standardised neuropsychological tests and a small number of experimental tasks which were either non-linguistic or drew to only a very basic degree on linguistic skills. Tests were grouped a priori into domains on the basis of available information about task characteristics and the type of executive abilities thought to be targeted by each task. Mental generativity and speed were assessed with the Delis-Kaplan Executive Function System (D-KEFS) Design Fluency subtest - filled and empty dots conditions, and Trail Making subtest - number and letter sequencing conditions (Delis, Kaplan, & Kramer, 2001). Working memory was assessed with the Keep Track task (Lee, Ng, & Ng, 2009; Yntema & Mueser, 1962), and the Wechsler Memory Scale, Spatial Span subtest (Wechsler, 1997). Set-shifting and switching were assessed with the Test of Everyday Attention, Visual Elevator subtest (Robertson, Ward, Ridgeway, & Nimmo-Smith, 1994), D-KEFS Design Fluency subtest - switching condition, and D-KEFS Trail Making subtest - switching condition (Delis et al., 2001). Inhibition and management of response conflict were assessed with the Simon task (Simon, 1969; computerised version, Gathercole et al., 2010), Go-No Go task (McNab et al., 2008), Test of Everyday Attention, Elevator Counting with Distraction subtest (Robertson et al., 1994), and Stroop Colour-Word Naming (Stroop, 1935; computerised version, Gathercole et al., 2010). Bilingual participants additionally completed a Welsh-language version of the Stroop task, not reported here, and the English and Welsh versions were administered in counterbalanced order; there were no significant differences in the bilinguals' mean response time difference scores on the English and Welsh versions for either colours or words, and in a three-way comparison of Stroop scores achieved on the English version by monolinguals, bilinguals who completed the Welsh version first, and bilinguals who completed the English version first there were also no significant between-group differences in mean response time difference scores for colours or words. Details of the computerised tasks can be found in Clare et al. (2014).

<u>Procedure</u>

Individuals expressing an interest in participating were visited by a researcher who explained the study further and sought informed consent. The assessment was then completed over two or three sessions. Participants were assessed either in their own homes or at the University, according to their preference. For bilingual participants, the structured interview was conducted in the language of their choice, the Welsh-language measures were administered in a session conducted through the medium of Welsh (with the exception of the Welsh-language version of the Stroop task, which was administered together with the other computerised tasks, but with instructions given in Welsh), and the remaining measures were administered in English.

Statistical analyses

Monolingual and bilingual groups were compared on socio-demographic factors and general cognitive ability using analysis of variance (ANOVA), Chi-square or Mann-Whitney tests. To provide contextual information, the two groups were also compared on tests of language ability in English using ANOVA. Performance on executive tasks within each of the four domains in the two groups was compared using ANOVA, applying the Holm-Bonferroni correction for multiple comparisons to all indices across the four domains, and effect sizes were calculated as the difference between the means for monolingual and bilingual groups, divided by the square root of the error mean square term from the ANOVA table (the pooled standard deviation). This provides the standardised mean difference. Multivariate analysis of variance (MANOVA) was applied to compare monolingual and bilingual performance within each of the four groups of executive tasks (mental generativity and speed, working memory, set-shifting and switching, and inhibition and management of response conflict), with Holm-Bonferroni correction for multiple comparisons applied across the analyses for the four domains. A further MANOVA compared monolingual and bilingual performance across all executive tasks. Within-group analysis for the bilingual group was conducted using two methods; sub-groups were identified based firstly on language use via cluster analysis and secondly on proficiency (Gollan et al., 2011), and compared using ANOVA.

Results

Sample characteristics are summarised in Table 1, with details of statistical comparisons between monolingual and bilingual groups on background measures. There were no significant differences between the two groups in age, gender, educational level, socio-economic status, health status, functional ability, or mood, and the two groups did not differ in scores on the Lifetime of Experiences Questionnaire, a proxy measure of cognitive reserve assessing engagement in complex mental activity across the lifespan. There were no significant differences in irregular word reading ability on the National Adult Reading Test-Revised. A small to medium effect size of .37 favoured monolinguals, but a bilingual disadvantage was expected for this English language-based task, reflecting less extensive exposure to English vocabulary. There were no differences between the two groups in cognitive status in terms of scores on the MMSE. As the two groups did not differ significantly on socio-demographic characteristics and other background measures, none of these factors was included as a covariate in subsequent analyses.

(((Table 1 near here)))

As expected in view of previous findings, monolinguals were superior to bilinguals in performance on English language tasks (see Table 2). Monolinguals achieved significantly higher scores on a lexical decision task and tests of vocabulary and picture naming, with medium to large effect sizes; these differences remained significant after Holm-Bonferroni correction for multiple comparisons.

(((Table 2 near here)))

Participants completed two tasks assessing mental generativity and speed, yielding three indices for comparison (see Table 3), Design Fluency and the Trail Making number sequencing and letter sequencing subtests. In univariate analyses there were no significant differences between monolinguals and bilinguals on any index. Small effect sizes favoured monolinguals in each case. Multivariate analysis revealed no significant differences between monolinguals and bilinguals in this domain (Wilks' Lambda = 0.94, F (3, 95) = 1.91, p = .133; monolingual n = 49, bilingual n = 50).

(((Table 3 near here)))

Two tasks assessing working memory yielded three indices for comparison (see Table 3). In univariate analyses, following Holm-Bonferroni correction, monolinguals showed a significant advantage on one index, Spatial Span forward score, with a medium effect size. For Spatial Span backward a medium effect size also favoured monolinguals, but the difference was not significant. There was no difference on the Keep Track task. Multivariate analysis indicated no significant differences between monolinguals and bilinguals in this domain following Holm-Bonferroni correction (Wilks' Lambda = 0.91, F (3, 85) = 2.95, p = .038; monolingual n = 43, bilingual n = 46).

Participants completed three tasks assessing set-shifting and switching, which yielded six indices for comparison (see Table 3). Monolinguals performed significantly better on the switching condition of the D-KEFS Design Fluency subtest, with a medium effect size, and this difference remained significant after Holm-Bonferroni correction. Medium effect sizes also favoured monolinguals for the Test of Everyday Attention Visual Elevator time per switch score and the D-KEFS Trail Making test number-letter sequencing completion time score, but these differences were not significant following correction for multiple comparisons. There were no differences on the two Test of Everyday Attention Visual Elevator accuracy indices and only a small effect favouring monolinguals for the D-KEFS Trail Making test number-letter sequencing accuracy. As two score indices for the visual elevator task (the total correct and total correct switch scores) were highly correlated, only the former was included in the multivariate analysis, as recommended by Dattalo (2013). Multivariate analysis indicated no significant differences between monolinguals and bilinguals in this domain after Holm-Bonferroni correction (Wilks' Lambda = 0.85, F (5, 79) = 2.80, p = .022; monolingual n = 46, bilingual n = 39).

Four tasks assessing inhibition and management of response conflict yielded five indices for comparison (see Table 3). A medium effect size favoured monolinguals for the Stroop word matching mean response time difference score and for the Test of Everyday Attention Elevator Counting with Distraction score, but neither of these reflected a significant difference after correction for multiple comparisons. There were no differences on Simon, Go-No Go or Stroop colour matching tasks. Multivariate analysis indicated no significant differences between monolinguals and bilinguals in this domain (Wilks' Lambda = 0.92, F (5, 87) = 1.54, p = .186; monolingual n = 49, bilingual n = 44).

Multivariate analysis across all executive tasks (except, as noted above, the visual elevator total correct switch score) indicated that overall there were no significant differences between monolinguals and bilinguals in executive task performance (Wilks' Lambda = .74, F (16, 60) = 1.34, p = .205; monolingual n = 40, bilingual n = 37).

Two methods were used to assess possible effects of degree of bilingualism on executive task performance in the bilingual group. The first method focused on language use. Hierarchical cluster analysis based on squared Euclidean distance was conducted for a 3 cluster solution using responses to three questions from the Language Questionnaire: 'approximately what percentage of the time do you speak Welsh on a daily basis?', 'approximately what percentage of time is Welsh currently spoken in the home', and 'on a scale of 1 to 5, how well do you feel you speak Welsh?' (where 1 is low, reflecting a lack of ability, and 5 is high, reflecting the ability to carry out virtually any kind of conversation). As responses to questions about frequency of use of English were the inverse of the percentage of time devoted to speaking Welsh, only the responses to questions about Welsh were used in the analysis. The 3 cluster solution yielded 3 groups consisting of 4, 10 and 35 individuals. Cluster 1 ($n = 4$) represented people who used Welsh infrequently (on average, on a daily basis 14% and in the home 5%) but were confident speakers (mean rating 4.75); Cluster 2 ($n = 10$) represented people who used Welsh almost half of the time (on average, on a daily basis 41% and in the home 48%) and were confident speakers (mean rating 5), and Cluster 3 ($n = 35$) represented individuals who spoke Welsh most of the time (on average, on a daily basis 82% and in the home 92%) and were confident speakers (mean rating 5). In view of the very small numbers in Cluster 1, further analyses were conducted with only Clusters 2 and 3. There were no significant differences between these two groups on demographic and background variables, and hence no possible covariates were identified. There were no significant differences between the groups on language tasks in English or Welsh, and no significant differences on any executive function measure.

The second method focused on proficiency using the approach described by Gollan et al. (2011). A bilingual index was calculated using the scores for English and Welsh versions of the Boston Naming Test. Scores for both versions are shown in Table 2. The bilingual participants scored significantly better on the English version than on the Welsh version (F (1, 48) = 29.60, $p < .001$); nine individuals obtained the same score in both languages, five had higher scores in Welsh and 35 had higher scores in English. The bilingual index is the proportion of pictures named correctly in the language with the lower naming score divided by the proportion of pictures named correctly in the language with the higher language score. The mean bilingual index score was 0.89 (sd = 0.09, range 0.60 - 1.00, $n = 49$). There were no significant associations with demographic and background variables, and therefore no variables were controlled for in further correlational analyses. Correlational analyses indicated that there were no significant associations between the bilingualism index and performance on other language tasks in English or Welsh, or any measure of executive function.

Discussion

In this study, we examined the performance of older Welsh/English bilinguals and monolingual English speakers on a range of tasks assessing aspects of executive control to determine whether there was evidence for a bilingual advantage in executive processing in this population. Taken together, the findings suggest that overall there are few significant differences in the cognitive profiles of monolinguals and bilinguals across a range of executive tasks. In contrast to recent research that has reported either a bilingual advantage (e.g. Bialystok et al., 2012) or no differences (e.g. Paap & Greenberg, 2013), however, the present results indicate a tendency for *monolinguals* to perform somewhat better across most task domains. These findings are consistent with results from another recent study comparing performance of Welsh/English bilinguals and English monolinguals at seven stages across the lifespan, ranging from pre-school to later life on dimensional card sorting, Simon, and meta-linguistic tasks (Gathercole et al., 2014), which found no evidence of a bilingual advantage but noted that, where differences between groups were observed, these favoured the monolingual group in almost all cases. They are also consistent with some other recent experimental studies focusing on different language combinations (Paap & Sawi, 2014). We will summarise and reflect on the profiles observed in each domain of executive function before considering possible explanations for these findings.

Across the 17 indices assessed, effect sizes > .2 favoured monolinguals in 10 cases, with small or negligible differences observed in the remaining 7 cases. Only two significant differences at the $p < 0.05$ level were observed, and these favoured monolinguals in both cases; monolinguals performed significantly better on Spatial Span forwards in the working memory domain and Design Fluency switching in the set-shifting and switching domain. This contrasts with previous findings showing that bilinguals perform better than monolinguals on Spatial Span tasks while monolinguals perform better on verbal tasks (Luo, Craik, Moreno, & Bialystok, 2013); as the Spatial Span task was similar to that used in the present study, this difference cannot be explained by the selection of different types of task.

Overall, our findings thus suggest that although in general there are few significant differences between the two groups, older Welsh/English bilinguals perform less well than monolinguals on some indices of executive function. It is important to consider how this pattern might be explained. In relation to the bilingual advantage, it has been argued that there is a need for greater understanding of the limits and boundary conditions for this effect, and of the possible reasons why it is not always found (Bialystok et al., 2012). Indeed, it has been suggested that 'questions arising from trying to understand failures to replicate a bilingual advantage may be potentially more interesting than clear demonstrations of the effect itself' (Baum & Titone, 2014, p. 881).

One possibility is that a bilingual advantage in older Welsh/English bilinguals could not be detected due to flaws in study design or the influence of other sources of variability; Valian (2015) suggests that there are many factors that can benefit cognitive function, and hence the specific benefits of bilingualism may be hard to detect, although Paap et al. (2015) propose that there is no bilingual advantage, and where benefits are identified, these can be explained with reference to other factors (but see Bak, 2015, for a critical commentary). A number of factors argue against the view that flaws in study design masked a bilingual advantage, in particular the converging evidence from age-groups across the lifespan (Gathercole et al., 2014), the careful attempts to control for possible confounding factors, the comparison of the two groups on a proxy measure of cognitive reserve, the inclusion of measures that have been used in other studies which did find the bilingual advantage, the use of a comprehensive set of executive function tasks to ensure that observed effects were not task-specific, and recruitment of a sample that was consistent with the size of, or larger in size than, those typically reported in similar types of study.

This leaves the possibility that Welsh/English bilinguals do not show a bilingual advantage of the kind found in some, but not all, other groups of bilinguals. That is to say, the bilingual advantage is observed under certain conditions and not under others, and older Welsh/English bilinguals fall into the latter category (Clare et al., 2014). These findings from an older Welsh sample, therefore, have a useful contribution to make with regard to helping to delineate the boundaries within which the bilingual advantage is observed and the factors which mitigate against its development or maintenance, as well as offering an opportunity to identify and consider possible reasons for the overall monolingual advantage observed in this study and in Gathercole et al. (2014).

Various explanations have been proposed to account for instances where no bilingual advantage has been found, and it is important to consider whether any of these explanations could be applied to account for the finding of a monolingual advantage in the present study. Some researchers have suggested that differences in socio-economic status or general cognitive ability between monolingual and bilingual groups may account for differences in performance (Bialystok, 2009; Gathercole et al., 2010; Morton & Harper, 2007). Given that socio-economic and socio-cultural diversity may be even more salient in relation to older samples than they are in the case of young adult samples, which often consist of university students, previous studies which have reported a bilingual advantage have made efforts to control for differences in socio-economic status (Bialystok et al., 2004; Bialystok, Craik, & Ryan, 2006). In the present study, the two groups did not differ significantly in socio-economic status or on other demographic variables, and hence differences in cognitive profile cannot readily be attributed to such factors. It has also been suggested that differences could be accounted for by differences in cognitive and linguistic abilities (Festman, Rodriguez-Fornells, & Munte, 2010; Gathercole et al., 2010). However, in our study, despite the language-based nature of the National Adult Reading Test-Revised and its reliance on exposure to English vocabulary, which could be expected to disadvantage bilingual participants, differences on this measure were not significant. Our assessment of language history, proficiency and usage in the monolingual and bilingual groups was in line with the findings of Luk and Bialystok (2013), who recommend a combination of self-reported proficiency and objective testing. While bilingual experience is diverse and complex, Welsh/English bilinguals are typically highly-proficient users of both languages with fairly similar language histories, and they can be clearly differentiated from monolingual English speakers. Exposure to Welsh in the home environment and among peers when growing up shape the use of Welsh in adulthood (Gathercole, 2007). With regard to the monolingual groups, it is not unusual for people born in Wales not to speak Welsh. This is especially the case with the cohort of interest here, as schooling in Welsh in state schools was not the norm in their youth. Like most English monolinguals, many of our participants had some experience of learning another language, but only at a basic level. Similar cognitive features to the bilingual advantage have been identified in people who become proficient in a second language and can be classed as late-acquisition bilinguals (Vega-Mendoza, West, Sorace, & Bak, 2015), but this is unlikely to be relevant for our monolingual group. Cognitive lifestyle scores indicated that the two groups were also comparable in terms of engagement in complex mental activity across the lifespan. As some studies reporting a significant bilingual advantage have compared bilinguals from immigrant communities with non-immigrant monolinguals, it has been suggested that factors associated with immigration status may explain the observed effects (Kousaie & Phillips, 2012). However, the bilingual advantage has frequently been documented in non-immigrant populations (e.g. Bialystok & Viswanathan, 2009; Costa et al., 2009; Costa et al., 2008; Kousaie & Phillips, 2012; Ljungberg, Hansson, Andres, Josefsson, & Nilsson, 2013). The sample in the present study was a non-immigrant sample from within the United Kingdom, so differences in the cognitive profiles in the monolingual and bilingual groups cannot be attributed to immigration status. Similarly, a recent study by Kirk, Fiala, Scott-Brown, and Kempe (2014) compared both older non-immigrant Gaelic-English bilinguals in Scotland and older immigrant Asian bilinguals with older British English monolinguals and found no differences in performance on the Simon task for either non-immigrant or immigrant bilinguals; in fact, there was a trend towards slower reaction times in one of the bilingual groups. de Bruin, Bak, and Della Sala (2015) also found no benefits of bilingualism in Gaelic-English bilinguals. Equally, the findings cannot be accounted for by the use of a range of different languages in the bilingual group (Gathercole et al., 2010; Kousaie & Phillips, 2012). A number of previous studies have found a bilingual advantage among bilinguals who share the same pair of languages (Bialystok et al., 2004; Gollan, Montoya, Cera, & Sandoval, 2008). In the present study, all the bilinguals shared the same pair of languages, Welsh and English, while all monolinguals spoke English. It has been suggested that language use and language dominance in the bilingual group may have an effect on cognitive test performance, since bilinguals are not a homogenous group, and truly balanced knowledge of both languages is rare (Gathercole & Thomas, 2009; Gathercole et al., 2010; Gollan et al., 2007; Zied et al., 2004). While it is important to acknowledge the extent of variability among bilinguals (Baum & Titone, 2014), no differences emerged when our bilingual sample was sub-divided according to frequency of using Welsh on a daily basis, or by means of the bilingualism index. It should be noted, however, that the latter, based on the Boston Naming Test, must be interpreted with caution; in addition to giving the task in its standard form in English, the bilingual participants were asked, in a separate Welsh-language session, to name the items in Welsh. This type of 'translational equivalent' going from one language to the other does not necessarily have the same status in the two languages, with differences in register or usage common (Peña, Bedore, & Fiestas, 2013). Finally, it has been suggested that some of the reported effects in bilingualism studies could reflect task-specific influences that do not generalise to other indices of executive function (Paap & Greenberg, 2013). Our grouping of tasks into broad domains of executive functioning based on existing evidence, while helpful in structuring the analysis, may have been imperfect as, despite recent advances (Miyake & Friedman, 2012), there is no clear consensus on the domains of executive function, and individual tasks necessarily draw on a range of abilities rather than reflecting a pure assessment of a single domain. However, our aim was to evaluate performance on a range of tasks considered to assess executive abilities, as recommended by Paap et al. (2015), including both tasks previously used to demonstrate a bilingual advantage and tasks that have not previously been examined in this regard, rather than to examine the nature of these tasks *per se*. There was no evidence for a bilingual advantage on any task. One further issue is whether the language in which the EF tasks was presented could have influenced performance, in that differences in proficiency in the test language might lead to differences in performance across individuals. This is unlikely to have been a factor here, however, since the tests were conducted in English and, as noted above, bilingual adults in Wales gain full and equivalent mastery of English across groups regardless of their level of Welsh (Gathercole, Kennedy, & Thomas, 2015; Gathercole & Thomas, 2009; Gathercole et al., 2010). In general, therefore, it seems that we must look for other factors that might underlie the unexpected finding of a monolingual advantage in older Welsh people.

Perhaps a more promising explanation relates to the context within which the bilinguals experience and use their two languages. A possible explanation put forward by Kousaie and colleagues based on their studies of monolingual English and French speakers and French/English bilinguals tested in Canada where, although there were some between-group differences, no clear evidence for a bilingual advantage was found (Kousaie & Phillips, 2012; Kousaie et al., 2014), is that the observed differences among the language groups might be due to the nature of the language environment and to the profile of language exposure and language use, and that these language-use differences affect the cognitive consequences of being monolingual or bilingual. Bilinguals in the present study shared the same two languages, and could be characterised as simultaneous or early sequential, rather than second-language bilinguals. The availability of both languages in the environment from an early stage, for both monolinguals and bilinguals, has implications for language acquisition and for the interaction of the two languages, and hence for the organisation and structure of relevant cognitive processes (Green & Abutalebi, 2013). It is possible that for these Welsh/English bilinguals, language use is a more automatic and less effortful process than it would be for second-language bilinguals (Gathercole et al., 2014), and lexical competition may be less frequently experienced than is the case for second-language bilinguals, so that fewer demands are placed on executive function. The linguistic and social experience of the bilinguals in the present study, like those of older French/English bilinguals in Montreal (Kousaie & Phillips, 2012), may have contributed to structuring cognitive processes in a way that is different to that observed in the bilingual samples in studies where the bilingual advantage is found. Possibly, differences in the way in which different groups of bilinguals use their two languages throughout their lives in their own social contexts can place different demands on executive control processes, leading to different patterns of performance on cognitive tests (Kirk et al., 2014).

One reason for conducting the present study was the possibility of documenting enhanced cognitive reserve in a Welsh bilingual sample. Previous work has suggested that being bilingual results in enhanced cognitive reserve and thus greater resilience in the face of age-related cognitive decline, extending to greater resistance to the effects of brain pathology resulting from the development of age-related neurodegenerative conditions such as Alzheimer's disease (Bialystok, Craik, Binns, Ossher, & Freedman, 2014; Bialystok et al., 2007) and stroke (Alladi et al., 2016). Clearly, in the present sample, the lack of a significant bilingual advantage might be considered to preclude the possibility of bilinguals accruing greater cognitive reserve as a result of specific differences in cognitive processing. Rather, the observation that monolinguals tend to perform better might suggest that the monolinguals are likely to have accrued greater cognitive reserve. However, use of a comprehensive combined proxy measure of cognitive reserve demonstrated that there were no differences between the monolingual and bilingual groups in the extent of engagement in complex mental activity across the lifespan, suggesting that bilinguals were not disadvantaged in this respect. Many different experiences, of which bilingualism is only one, are associated with both cognitive reserve and executive function ability (Valian, 2015). The focus of this study was on behavioural differences, and we did not examine whether there were differences in brain functioning in the two groups. Differences in brain functioning between monolinguals and bilinguals have been documented (Gold, 2015; Li, Legault, & Litcofsky, 2014) but as these do not align with behavioural differences, and similar behavioural outcomes may be underpinned by different types of neural activity (Paap et al., 2015; Valian, 2015), it is unlikely that a focus on brain functioning in the present study would have provided an explanation for the observed lack of a bilingual advantage.

To conclude, when comparing older Welsh/English bilinguals and English-speaking monolinguals living in North Wales, the overall pattern was of few clear differences, with a tendency for monolinguals to perform better in some domains. Further research is required to establish the reasons why the bilingual advantage is observed in some groups of bilinguals but not others, to fully distinguish the characteristics of bilingual groups where the effect is, or is not, found, and to elucidate the reasons for the relatively stronger performance of monolinguals in Welsh samples, which may relate to aspects of the socio-linguistic context.

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Table 1. Characteristics of monolingual and bilingual groups, and statistical comparisons

Measure (min-max)	Monolingual n = 49 mean (sd, range) or frequency	Bilingual n = 50 mean (sd, range) or frequency	ANOVA, Chi-square or Mann-Whitney U
Age	72.55 (8.06, 60 - 94)	74.32 (9.03, 61 - 97)	F (1, 97) = 1.06, p = .307
Gender	Female 28, male 21	Female 31, male 19	χ^2 (1) = 0.24, p = .622
Educational level			χ^2 (4) = 3.54, p = .471
No formal qualifications	6	8	
secondary school	3	5	
further education/vocational	20	15	
university degree	12	14	
higher degree	8	8	
Socio-economic status*			χ^2 (8) = 4.14, p = .844
Professional	12	5	
managerial and technical	22	29	
skilled non-manual	8	8	
skilled manual	2	4	
partly skilled	4	4	
unskilled	1	0	
Health status: EQ-5D visual analogue scale (0 - 100)	75.14 (16.56, 30 - 100)	77.67 (17.76, 30 - 100, n = 48)	F (1, 95) = 0.52, p = .471
Functional ability: IADL (0 - 8)	7.88 (0.39, 6 - 8)	7.72 (0.67, 5 - 8)	F (1, 97) = 2.03, p = .157
HADS Anxiety (0 - 21)	5.37 (3.78, 0 - 16)	6.02 (3.79, 0 - 18)	F (1, 97) = 0.74, p = .393
HADS Depression (0 - 21)	3.22 (2.17, 0 - 10)	3.06 (2.44, 0 - 11)	F (1, 97) = 0.13, p = .724

Lifetime of Experiences Questionnaire	117.87 (26.19, 59.00 - 158.30)	114.77 (31.99, 57.20 - 175.50, *n* = 49)	*F* (1, 96) = 0.28, *p* = .601
National Adult Reading Test-Revised error score (50 - 0)	10.08 (7.27, 1 - 36)	12.94 (8.35, 2 - 38, *n* = 49)	*F* (1, 96) = 3.26, *p* = .074
Mini-Mental State Examination (0-30)	29.22 (0.92, 26 - 30)	28.80 (1.21, 26 - 30)	z = -1.66, *p* = .097

Abbreviations: Hospital Anxiety and Depression Scale (HADS), Instrumental Activities of Daily Living (IADL)

*Classification based on occupation (Office for National Statistics, 2010).

Table 2. Monolingual and bilingual performance on tasks assessing English language ability, comparison of group means, and effect sizes, and bilingual performance on tasks assessing Welsh language ability

Measure (possible score range)	Monolingual *n* = 49 mean (sd, range)	Bilingual *n* = 50 mean (sd, range)	ANOVA	Effect size (SMD) for language group
Spot-the-Word (0 - 60)^	55.39 (3.52, 46 - 60)	51.73 (5.41, 40.5 - 60, *n* = 49)	*F* (1, 96) = 15.77, *p* < .001*	.80 ML > BL
British Picture Vocabulary Scale (0 - 60)	58.39 (1.73, 52 - 60)	55.98 (4.11, 45 - 60)	*F* (1, 97) = 15.50, *p* < .001*	.75 ML > BL
Boston Naming Test (0 - 15)	14.49 (0.98, 11 - 15)	13.94 (1.33, 10 - 15, *n* = 49)	*F* (1, 96) = 5.45, *p* = .022*	.47 ML > BL
Boston Naming Test in Welsh (0 - 15)		12.76 (1.75, 8 - 15, *n* = 49)		
Prawf Geirfa Cymraeg i Oedolion (0 - 84)		68.94 (6.42, 44 - 74, *n* = 47)		

Abbreviations: standardised mean difference (SMD)

*Significant after Holm-Bonferroni correction across all 3 indices

^On Spot-the-Word, for the 7 monolinguals and 15 bilinguals who had <10 missing items, scores were imputed in line with test instructions.

Table 3. Monolingual and bilingual performance on tests of executive function, comparison of group means, and effect sizes

Measure (possible score range)	Monolingual *n* = 49 mean (sd, range)	Bilingual *n* = 50 mean (sd, range)	ANOVA*	Effect size (SMD) for language group
<u>Tests assessing mental generativity and speed</u>				
D-KEFS Design Fluency proportion correct (%) (0 - 100)	82.53 (13.05, 32 - 100)	77.96 (13.26, 47 - 96)	F (1, 97) = 2.98, p = .088	.35 ML > BL
D-KEFS TMT number sequencing time to complete (max 150 secs)	49.49 (18.24, 26 - 109)	59.92 (33.42, 18 - 150)	F (1, 97) = 3.70, p = .058	.39 ML > BL
D-KEFS TMT letter sequencing time to complete (max 150 secs)	50.20 (22.04, 21 - 121)	59.76 (31.75, 20 - 150)	F (1, 97) = 3.02, p = .086	.35 ML > BL
<u>Tests assessing working memory</u>				
Keep Track task total correct (0 - 12)	8.19 (1.95, 4 - 12, *n* = 47)	8.30 (1.73, 5 - 12, *n* = 46)	F (1, 91) = 0.09, p = .768	.07 BL > ML
WMS Spatial Span forward total correct (0 - 16)	7.23 (1.51, 4 - 10, *n* = 48)	6.24 (1.63, 4 - 10, *n* = 49)	F (1, 95) = 9.56, p = .003*	.63 ML > BL

WMS Spatial Span backward total correct (0 - 16)	6.89 (1.64, 4 - 10, *n* = 45)	6.04 (1.93, 2 - 9)	*F* (1, 92) = 5.24, *p* = .024	.47 ML > BL
<u>Tests assessing set-shifting and switching</u>				
TEA Visual Elevator total correct (0 - 10)	8.58 (1.72, 3 - 10, *n* = 48)	8.46 (1.78, 2 - 20, *n* = 41)	*F* (1, 87) = 0.10, *p* = .748	.07 ML > BL
TEA Visual Elevator total correct switches (0 - 40)	34.46 (7.00, 12 - 40, *n* = 48)	33.98 (7.48, 6 - 40, *n* = 41)	*F* (1, 87) = 0.10, *p* = .754	.07 ML > BL
TEA Visual Elevator time per switch (seconds)	4.35 (1.52, 2.2 - 11.6, *n* = 48)	5.06 (1.53, 2.8 - 10.6, *n* = 41)	*F* (1, 87) = 4.74, *p* = .032	.47 ML > BL
D-KEFS Design Fluency switching total correct (0 - 35)	7.73 (2.17, 2 - 12)	6.14 (2.31, 2 - 12)	*F* (1, 97) = 12.52, *p* = .001*	.71 ML > BL
D-KEFS TMT number-letter sequencing time to complete (max 240 secs)	100.32 (44.87, 49 - 240, *n* = 47)	129.47 (57.80, 47 - 240, *n* = 47)	*F* (1, 92) = 7.46, *p* = .008	.56 ML > BL
D-KEFS TMT number-letter sequencing set loss errors	0.40 (0.88, 0 - 5, *n* = 47)	0.55 (0.86, 0 - 3, *n* = 47)	*F* (1, 92) = 0.70, *p* = .406	.17 ML > BL

Tests assessing inhibition and management of response conflict				
TEA Elevator Counting with Distraction total correct (0 - 10)	7.86 (2.66, 1 - 10)	7.02 (3.04, 0 - 10, *n* = 46)	*F* (1, 93) = 2.04, *p* = .157	.29 ML > BL
Simon task mean response time difference (incongruent minus congruent)	89.59 (144.07, -233 - 613)	79.59 (212.95, -359 - 930, *n* = 49)	*F* (1, 96) = 0.07, *p* = .786	.06 BL > ML
Go-No Go commission errors	0.80 (1.17, 0 - 4)	0.85 (1.10, 0 - 5, *n* = 48)	*F* (1, 95) = 0.03, *p* = .872	.03 ML > BL
Stroop colour matching mean response time difference (incongruent minus congruent)	718.51 (1211.71, -559 - 8266)	762.13 (553.16, -141 - 2403, *n* = 47)	*F* (1, 94) = 0.05, *p* = .822	.05 ML > BL
Stroop word matching mean response time difference (incongruent minus congruent)	12.81 (278.05, -999 - 714)	147.87 (304.74, -715 - 1296, *n* = 47)	*F* (1, 94) = 5.15, *p* = .025	.46 ML > BL

*Significant after Holm-Bonferroni correction across all 17 indices

Abbreviations: Delis-Kaplan Executive Function System (D-KEFS), Trail Making test (TMT), Wechsler Memory Scale (WMS), Test of Everyday Attention (TEA), Bilingual (BL), Monolingual (ML), standardised mean difference (SMD)