

Integrating bilingualism, verbal fluency, and executive functioning across the lifespan

Zhen Zeng¹, Marina Kalashnikova^{2,1}, Mark Antoniou¹

¹The MARCS Institute for Brain, Behaviour and Development, Western Sydney University,
Australia

²BCBL. Basque Center on Cognition, Brain and Language, Spain

Corresponding author: Marina Kalashnikova, BCBL. Basque Center on Cognition, Brain and
Language, Mikeletegi Pasealekua, 69, San Sebastian, Gipuzkoa, 20009, Spain, +34 943 309
300 (ext: 234), m.kalashnikova@bcbl.eu .

Acknowledgements: This work was supported by a Western Sydney University Researcher
Development Women's Fellowship Award to the second author and an Australian Research
Council Discovery Early Career Research Award DE150101053 to the third author. We
thank all the children and adult participants for their valuable time and interest in this
research.

Reference:

Zeng, Z., Kalashnikova, M., & Antoniou, M. (in press). Integrating bilingualism, verbal
fluency, and executive functioning across the lifespan. *Journal of Cognition and
Development*.

BILINGUALISM, VERBAL FLUENCY, AND EXECUTIVE FUNCTIONING

Bilingual experience has an impact on an individual's linguistic processing and general cognitive abilities. The relation between these linguistic and non-linguistic domains, in turn, is mediated by individual linguistic proficiency and developmental changes that take place across the lifespan. This study evaluated this relationship by assessing inhibition skills, and verbal fluency in monolingual and bilingual school-aged children (Experiment 1), young adults (Experiment 2), and older adults (Experiment 3). Results showed that bilinguals outperformed monolinguals in the measure of inhibition, but only in the children and older adult age groups. With regards to verbal fluency, bilingual children outperformed their monolingual peers in the letter verbal fluency task, but no group differences were observed for the young and old adults. These findings suggest that bilingual experience leads to significant advantages in linguistic and non-linguistic domains, but only at the time points when these skills undergo developmental changes.

Keywords: bilingual advantage, bilingualism, executive function, verbal fluency, Simon effect, vocabulary

BILINGUALISM, VERBAL FLUENCY, AND EXECUTIVE FUNCTIONING

Bilingual experience appears to impact individuals' performance on measures of linguistic processing and non-linguistic general cognitive skills in opposite ways (see Kroll & Bialystok, 2013 for a review). On the one hand, a bilingual advantage has been uncovered in the general cognitive domain, particularly when executive functions are assessed. This suggests that bilinguals' life-long experience of selectively processing and using two language systems has shaped more general cognitive processes involved in inhibition, allocation of attention, and working memory (e.g., Adesope, Lavin, Thompson, Ungerleider, 2010; Antoniou, 2019; Bialystok, 2018 for reviews). On the other hand, monolinguals have been found to outperform bilinguals in a variety of tasks that assess linguistic processing, which, in turn, has been attributed to bilinguals' reduced exposure to and usage of each language (Bialystok & Feng, 2011; Gollan & Kroll, 2001; Michael & Gollan, 2005; Oller & Eilers, 2002; Portocarrero, Burright, & Donovan, 2007). However, performance on some linguistic processing tasks may be dependent not only on participants' bilingual status, but also on the complex interaction between their individual linguistic proficiency, general executive functioning abilities, and developmental changes in both linguistic and non-linguistic domains that occur across the lifespan. The present study focuses on evaluating these interactions by assessing monolingual and bilingual performance in non-verbal measures of inhibition and measures of verbal fluency and exploring how these interactions change across the lifespan by examining school-aged children, young adults, and older adults. Next, we review the literature pertinent to the effects of bilingualism and maturational factors on executive functioning and verbal fluency respectively, followed by three experiments that assessed the relations between these factors in school-aged children (Experiment 1), young adults (Experiment 2), and old adults (Experiment 3).

Bilingualism Effects on Executive Functioning

BILINGUALISM, VERBAL FLUENCY, AND EXECUTIVE FUNCTIONING

An advantage in executive functioning skills has been widely documented across bilingual populations when they are compared to same-age monolinguals (see Antoniou, 2019 for a recent review). This bilingual advantage has been attributed to advanced attentional processes (Bialystok, 2018), specifically bilinguals' ability to selectively allocate their attentional resources particularly in cognitively demanding or effortful tasks like those that involve conflicting information.

One task that is commonly used in studies on executive functioning in monolingual and bilingual populations is the Simon arrows task, which is an adaptation of the classic Simon task (Bialystok, Craik, Klein, & Viswanathan, 2004). In this version, participants are presented with arrays of arrows on the screen and are required to attend to the direction in which the central arrow is pointing while ignoring the position of the arrows located to its left and right. Critically, the task involves four types of trials: neutral, opposite, congruent, and incongruent. On neutral trials, participants indicate the direction that a centrally-located arrow is pointing. This is used as training and does not rely on executive functioning skills. Opposite trials require participants to respond in the opposite direction to the onscreen arrow, and thus incur response inhibition. The two conflict conditions present the arrow on the left or right sides of the screen. Congruent trials are those in which the stimulus position and arrow direction correspond, incurring conflict monitoring. Incongruent trials are those in which the stimulus position and arrow direction are in conflict, incurring interference suppression. Using this task, bilinguals have been demonstrated to achieve faster reaction times in both congruent and incongruent trials (Bialystok et al., 2004; Bialystok, Martin, & Viswanathan, 2005) suggesting that bilinguals are more successful than monolinguals not only at suppressing interference in the challenging incongruent trials, but also at adapting to the executive attention demands of the entire task (Costa, Hernández, Costa-Feidella, & Sebastián-Gallés, 2009).

Evidence for bilingual effects on executive functioning across the lifespan. The bilingual advantage for executive functions also appears to be modulated by participants' age and their individual linguistic experiences and patterns of language use (e.g., De Bruin, Treccani, & Della Sala, 2015; Duñabeitia et al., 2014; Paap, Johnson, & Sawi, 2015). While several studies have demonstrated that bilingual young adults outperform monolinguals on some executive functioning tasks (Bialystok, Craik, & Luk, 2008a; Bialystok, Poarch, Luo, & Craik, 2014; Costa et al., 2009; Costa, Hernández, & Sebastián-Gallés, 2008), others have failed to capture any differences in performance (Gathercole et al., 2014; Kousaie, Sheppard, Lemieux, Monetta, & Taler, 2014; Salvatierra & Rosselli, 2011), and this has generated a lively debate (Antoniou, 2019). In light of this evidence, it has been suggested that the effects of bilingualism on cognitive functions are more likely to be observed at some points across the lifespan (childhood, older adulthood) than others (young adulthood).

For instance, Bialystok et al. (2005) assessed Simon task performance in school-aged children, young, middle-aged, and older adult monolingual and bilingual participants. Their findings, showed that the bilingual advantage was only observed in childhood and later adulthood and not among young adults. Thus, it was proposed that during childhood, when executive functioning skills are being developed and consolidated, bilingualism boosts development, and during older age, bilingualism counteracts and protects against age-related cognitive decline. In the case of young adults, bilingual advantages are difficult to detect using behavioural tasks. One reason that has been offered is that executive functions are at their peak at this age, which attenuates the group differences seen in children and elderly participants. In line with this interpretation, Salvatierra and Roselli (2011) compared monolingual and bilingual Spanish-English younger and older adults using a squares Simon task with simple and complex versions. Their results showed that only older bilinguals outperformed their monolingual counterparts, and this was true only for the simple version of

BILINGUALISM, VERBAL FLUENCY, AND EXECUTIVE FUNCTIONING

the task which tapped inhibitory control without the additional requirements for working memory. On the other hand, Bialystok and colleagues (Bialystok et al., 2004; Martin-Rhee & Bialystok, 2008) showed that the bilingual effect in the Simon task trials was present both among their younger and older participants. The discrepancy between studies is puzzling, and it may be due to a number of confounding factors such as differences in bilingual populations and task demands (Bak, 2016). Importantly, all these studies reinforced the conclusion that while there is an observed decline in executive functioning in old age, bilingualism ameliorates the effects of ageing.

Effects of Bilingualism on Verbal Fluency

Contrary to the evidence from non-verbal measures reviewed above, when performance is assessed in the verbal domain, monolinguals tend to outperform their bilingual counterparts (Bialystok & Feng, 2009; Oller & Eilers, 2002; Portocarrero et al., 2007). Such findings are often encountered in tasks that rely on expressive language skills such as measures of lexical retrieval (Bialystok & Feng, 2009; Roberts, Garcia, Desrochers, & Hernandez, 2002) or verbal fluency (Gollan & Kroll, 2001; Michael & Gollan, 2005) where bilinguals tend to produce higher rates of errors and tip-of-the-tongue instances (Gollan & Acenas, 2004). The difficulties in performance faced by bilinguals are often attributed to their reduced exposure and competence in each language, and the requirement to constantly monitor their languages and suppress the language that is not in use during the task. However, this raises a question about the extent to which bilinguals' advanced executive functioning skills support their performance in the linguistic domain at different stages of development.

A commonly used task to assess verbal fluency in children and adults is the Verbal Fluency Task (VFT) (Strauss, Sherman, & Spreen, 2006). VFTs require the participant to name as many words as possible within a set time belonging to a single semantic category

BILINGUALISM, VERBAL FLUENCY, AND EXECUTIVE FUNCTIONING

(category VFT) or beginning with a given letter of the alphabet (letter VFT). These two VFT conditions impose different demands on linguistic processing and executive functions allowing for specific predictions regarding the effects of bilingualism on performance. The category VFT imposes demands that are similar to everyday lexical retrieval, and therefore, taps participants' lexical knowledge (of one of their languages in the case of bilinguals) (Levelt, 1999; Luo, Luk, & Bialystok, 2010; Sandoval, Gollan, Ferreira, & Salmon, 2010). The letter VFT also relies on lexical competence, but unlike category VFT, it imposes additional demands on attentional skills such as interference suppression (Perret, 1974; Schmidt et al., 2017). That is, participants are required to suppress the semantically related competitors activated during the task in order to only retrieve the target lexical items. In light of this dissociation, bilinguals can be expected to show lower performance than monolinguals in category VFT given that their vocabulary size in each of their languages tends to be lower compared to their monolingual peers. On the contrary, a bilingual advantage might be expected for letter VFT as a consequence of a bilingual advantage in executive functioning skills.

Evidence for bilingual effects on verbal fluency across the lifespan and language proficiency levels. Existing bilingual VFT research findings highlight the complex relationship between lexical proficiency and general cognitive skills. That is, when lexical competence is not formally assessed, or it is not ensured that the monolingual and bilingual samples have comparable target language vocabulary sizes, a bilingual disadvantage is observed both in the category and letter VFTs (Gollan, Montoya, & Werner, 2002; Rosselli et al., 2000, 2002). However, when language proficiency is taken into account, differing patterns are observed in children and adults. For instance, Friesen, Luo, Luk, and Bialystok (2015) assessed VFT performance in 10-year-old monolingual and bilingual children, and although the bilinguals had significantly smaller English vocabulary sizes than monolinguals,

BILINGUALISM, VERBAL FLUENCY, AND EXECUTIVE FUNCTIONING

VFT performance did not differ between the groups, suggesting that bilinguals were able to overcome the gap in lexical competence by engaging their executive functioning skills. This conclusion is complemented by Pino-Escobar, Kalashnikova, and Escudero (2018) who assessed VFT and executive functioning performance in monolingual and bilingual eight-year-old children who did not differ in their English vocabulary size. Their findings showed that bilinguals outperformed monolinguals on both the category and letter VFTs. Importantly, regression analyses confirmed that children's English vocabulary and executive functioning scores predicted performance on letter VFT, but only English vocabulary predicted performance on the category VFT.

In the case of younger and older adults, bilinguals outperform monolinguals on the letter and not category VFT, but only when the two samples have comparable vocabulary sizes in the target language (Friesen et al., 2015). Luo et al. (2010) directly measured the effects of vocabulary on VFT performance by comparing a group of monolinguals to two bilingual groups: one with vocabulary scores comparable to monolinguals (high vocabulary group) and the other with vocabulary scores lower than monolinguals (low vocabulary group). Their findings indicated that the high vocabulary bilinguals outperformed monolinguals on the letter VFT, but the low vocabulary bilinguals did not. Friesen et al. (2015) assessed VFT performance across the lifespan and also found a bilingual advantage in letter VFT in both younger and older adults. These findings suggest that neither lexical knowledge nor bilingual status alone are sufficient to account for the differences in performance observed between bilinguals and monolinguals in this task. It is noteworthy, however, that in samples of elderly participants, performance in the semantic or category VFT correlates with cognitive and linguistic processes that extend beyond vocabulary knowledge. For instance, Shao, Janse, Visser, and Meyer (2014) assessed the relation between letter and category VFT performance, lexical skills, and executive functioning in monolingual older

BILINGUALISM, VERBAL FLUENCY, AND EXECUTIVE FUNCTIONING

adults. Similar to the previous findings with children and young adults, vocabulary knowledge predicted both category and letter VFT performance. Crucially, this was also the case for executive functioning skills; specifically for older adults, and unlike findings with younger participants, there was no evidence that executive functioning made a greater contribution to letter than to category VFT performance.

The Present Study

As can be seen, previous literature points to a complex interaction between the effects of bilingualism on executive functioning, linguistic processing abilities, and individual linguistic competence. Importantly, these interactions manifest differently across the lifespan, specifically when monolingual and bilingual samples are compared at developmental time points when they have full access to cognitive resources (young adulthood) and time points when individuals undergo significant developmental cognitive changes (childhood and older adulthood). The present study assessed monolingual and bilingual performance on measures of linguistic knowledge in the target language, executive functioning, and verbal fluency in school-aged children, young adults, and older adults. The inclusion of the three age groups enabled this study to track the effects of bilingual status on performance across the life span, and to systematically assess the relationship between performance in the three domains at each developmental time point.

Letter and category VFTs and the Simon Arrows task were selected to assess bilingual and monolingual skills of executive functioning and lexical retrieval. Three groups of monolinguals and bilinguals were tested in three experiments: school-aged children (Experiment 1), young adults (Experiment 2), and older adults (Experiment 3). In addition to the experimental tasks, all participants completed measures of vocabulary size in the target language (in this case English) and bilinguals completed reports on their proficiency and

BILINGUALISM, VERBAL FLUENCY, AND EXECUTIVE FUNCTIONING

patterns of use of their two languages. The following two sets of predictions were constructed for the two measures included here.

(1) *Verbal fluency*: in the cases where the two groups have comparable English vocabulary sizes, bilinguals were expected to outperform monolinguals on letter VFT, and no performance difference was expected for the category VFT condition. In the cases where monolinguals have larger English vocabulary sizes, bilinguals were expected to underperform monolinguals in the category VFT, but no performance differences were expected for letter VFT (Friesen et al., 2015; Pino-Escobar et al., 2018).

(2) *Executive functioning*: a bilingual advantage manifested in lower reaction times and greater accuracy was expected for the two types of trials of the conflict condition of the task (congruent and incongruent) since the task used here presented these two types of trials in a random order and not in separate blocks (Bialystok et al., 2004, 2005; Costa et al., 2009). Furthermore, we predicted that the bilingual advantage would only be observed for children and older adults and not for the younger adults in this study (Bialystok et al., 2005).

General Method

The present study involved three groups of monolingual and bilingual participants: children (6-10 years of age), young adults (19-30 years of age), and older adults (60-80 years of age). All participants completed a language background questionnaire about their patterns of language exposure and language use, standardised measures of receptive and productive vocabulary, letter and category VFTs, and the arrows version of the Simon task. Except for the language background questionnaires, all tasks and procedures implemented with the three age groups were identical, and they are described in detail below.

Receptive and Productive Vocabulary

The Peabody Picture Vocabulary Test IV (PPVT) (Dunn & Dunn, 2007) and the Expressive Vocabulary Test II (EVT) (Williams, 1997) were administered as measures of

BILINGUALISM, VERBAL FLUENCY, AND EXECUTIVE FUNCTIONING

English receptive and expressive vocabulary size respectively. In the PPVT, participants are shown four images on a card and are asked to point to the image that depicts the target word said by the experimenter. In the EVT, participants are shown an image on a card and are asked to name the image. A standardised score is computed for each test ($M = 100$, $SD = 15$).

Verbal Fluency Tasks

In these tasks, participants were asked to produce as many words as possible during a 60 second period. In the letter VFT, participants were asked to produce words that started with the letter 'f'. In the category VFT, they were asked to produce words that were names of animals. In addition, participants were instructed to omit proper nouns (e.g., Frank, France) and morphologically related words (e.g., fast, faster, fastest). The order of administration of the two VFT conditions was counterbalanced across participants. During the task, the experimenter counted participants' responses. Scores were calculated by subtracting any incorrect answers (answers that did not follow the rules described above, non-words, and repetitions of the same word) from the total number of produced answers.

Simon Arrows Task

The Simon Arrows task contained three conditions comprising a total of 80 trials: neutral, opposite, and conflict. The experiment consisted of three blocks of trials (one block for each condition), and all participants completed the three blocks in the same order: neutral, opposite, and conflict. First, the neutral condition (20 trials) presented an arrow pointing either left or right in the centre of the display, and participants were required to press the left or right response key to indicate the direction of the arrow as quickly as possible. Second, in the opposite condition (20 trials), arrows were presented centrally on the screen but participants were instructed to press the arrow key pointing in the opposite direction to that indicated by the onscreen arrow. Third, the conflict condition (40 trials) presented arrows on the left or right side of the display, rather than in the centre. Participants were instructed to

BILINGUALISM, VERBAL FLUENCY, AND EXECUTIVE FUNCTIONING

indicate which direction the arrow was pointing, similarly to the neutral condition. However, in the conflict condition, an arrow could be pointing to the left but be located on the right side of the screen (and vice versa), or both be located and be pointing to the left (or right). The conflict condition contained 40 trials in total with 20 congruent and 20 incongruent trials presented in random order.

The task was administered via E-Prime 2.0 software (Schneider, Eschman, & Zuccolotto, 2002) on a 13.5 inch laptop. Participants responded by pressing the left and right Shift keys on the keyboard, which were marked with colourful stickers. Participants were instructed to respond as quickly as possible without making errors, and they were reminded of the instructions before the start of each block. If participants did not respond within 5 seconds, the screen prompted “Please respond faster”, and then automatically moved on to the next trial. For the analysis, response accuracy (% correct) and the response times (RT) for correct trials only (raw RTs were converted from ms to z -scores for analyses) were calculated separately for neutral, opposite, congruent conflict, and incongruent conflict trials.

All tasks were administered by an English-speaking experimenter in English. Sessions were administered in a laboratory room or in a quiet room inside a public library. During the tasks, participants sat at a desk in front of the experimenter. Parents or caregivers of the children were present in the room during the session, but were instructed to remain silent to avoid any distractions. Tasks were administered in the fixed order: Simon task, VFT, PPVT and EVT.

Experiment 1

Participants

Thirty-seven children between 6-10 years of age were included in this study. Seventeen children were monolingual speakers of Australian English (9 females; M age = 8.3 years; SD = 1.5; range 6 to 10.55 years), and twenty children were bilingual speakers of

BILINGUALISM, VERBAL FLUENCY, AND EXECUTIVE FUNCTIONING

Australian English and one additional language (12 females; M age = 8.3 years; SD = 1.2; range 6.48 to 10 years). Children's age did not differ significantly between the two groups, $t(35) = .190$, $p = .850$, $d = .064$. An additional nine children participated but were excluded from the final sample; six reported developmental disorders or language delays (stuttering, Autism Spectrum Disorder, general language delay), and three were too old and did not satisfy the selection criteria. Children were recruited through advertisements placed in local community centres, word of mouth, and by contacting parents who had expressed interest in taking part in research at a university infant laboratory.

In order to collect information about children's language proficiency and exposure, each child's main caregiver was asked to complete the Language Background Questionnaire (adapted from Sabourin, Leclerc, Lapierre, Burkholder, & Brien, 2016). In this questionnaire, caregivers are asked to provide detailed information about their children's proficiency in their two languages and their patterns of language exposure and use.

All bilingual children were reported to receive exposure to the additional language and to Australian English at home and in school. Children's additional languages were Mandarin (17), Shanghainese (1), Arabic (1), and Spanish (1). One child had acquired two languages from birth, and the remaining children acquired their heritage language from birth, and were first exposed to English between the ages of 1 to 4 years of age ($M = 2.95$ years; $SD = 0.85$). Parents were asked to indicate the amount of time in an average week that their child was exposed to English and to their additional language. Children's English exposure ranged from 50-85% ($M = 67.5\%$, $SD = 9.82$). At a glance, this range suggests that some children received significantly more exposure to one of their languages than what would be commonly accepted as a criterion to consider a child participant bilingual (e.g., a minimum of 25% exposure to the non-dominant language, Pearson, Fernandez, Lewedeg, & Oller, 1997). However, questionnaire data also indicated that children interacted in their additional

BILINGUALISM, VERBAL FLUENCY, AND EXECUTIVE FUNCTIONING

language with their primary caregivers at home (for 14 children, one parent only used the additional language to speak to the child and the other used the additional language in combination with English, and for 6 children both parents used a combination of the additional language and English). Therefore, although these children received a large amount of English exposure *at the time of testing*, which is not surprising given that they were attending English-only schools, they were raised in strictly bilingual environments with exposure to a language other than English as their primary home language.

Children's English language proficiency was assessed using measures of receptive and expressive vocabulary size (see General Method). Monolingual and bilingual receptive and expressive vocabulary scores did not differ (see Table 1). No measure of their proficiency in the additional language was available. Therefore, parents were asked to rate their children's comprehension and production skills in the additional language on a scale from 0 to 5 (0 very low ability, 1 low, 2 intermediate, 3 advanced, 4 near-native, and 5 native-like). The majority of bilingual children were reported to have advanced (or greater) proficiency in both comprehension and production. Specifically, for comprehension, 8 children were reported to have native-like ability, 6 near-native, 1 advanced, and 5 intermediate, and none had low or very low ability ($M = 3.85$, $SD = 1.22$). For production, 8 children were reported to have native-like ability, 5 near-native, 2 advanced, 5 intermediate, and none had low or very low ability ($M = 3.8$, $SD = 1.24$).

<Insert Table 1 about here>

Results

The sample included in Experiment 1 comprised children between 6 and 10 years of age, an age range when significant developmental changes to executive functioning take place. In order to account for these developmental effects as well as for their potential

interaction with the effect of bilingualism that was the main focus of this study, all Analyses of Variance reported below included children's age in years as a covariate.

Verbal fluency tasks. Monolingual and bilingual children's VFT scores are shown in Figure 1. Performance was compared separately for each version of the VFT using Univariate Analyses of Covariance (ANCOVA). For the category VFT, the ANCOVA yielded a main effect of age, $F(1, 34) = 7.076, p = .012, \eta_p^2 = .172$, but no effect of group, $F(1, 34) = .810, p = .374, \eta_p^2 = .023$, as monolinguals ($M = 14.66, SD = 1.17$) and bilinguals ($M = 16.09, SD = 1.07$) obtained scores that did not differ statistically. In the letter VFT, however, there was a significant effect of age, $F(1, 34) = 10.010, p = .003, \eta_p^2 = .227$, but also a significant effect of group, $F(1, 34) = 6.919, p = .013, \eta_p^2 = .169$. Bilinguals ($M = 8.50, SE = .778$) obtained significantly higher scores than monolinguals ($M = 5.47, SE = .844$) in this version of the task.

<Insert Figure 1 about here>

Simon task.

Simon conditions.

Accuracy. Children's accuracy scores for the neutral, opposite, and conflict Simon conditions are shown in Figure 2A. Data were screened for outliers and statistical assumptions were deemed satisfactory. We conducted a $2 \times (3)$ ANCOVA on the children's accuracy scores with the between-subjects factor of Group (monolinguals vs. bilinguals) and the within-subjects factor of Simon Condition (neutral vs. opposite vs. conflict) and age as the covariate. A main effect of group, $F(1, 34) = 28.653, p < .001, \eta_p^2 = .457$, revealed that, overall, bilingual children performed better than monolinguals. The effect of age did not reach statistical significance, $F(1, 34) = 3.574, p = .067, \eta_p^2 = .095$. Mauchly's test of sphericity was significant indicating that the sphericity assumption was violated, and thus we applied a Huynh-Feldt adjustment to the degrees of freedom. There was a main effect of

BILINGUALISM, VERBAL FLUENCY, AND EXECUTIVE FUNCTIONING

Simon condition, $F(1.376, 48.17) = 5.005, p = .013, \eta_p^2 = .233$, and a significant Group \times Simon Condition interaction, $F(1.376, 48.17) = 6.725, p = .004, \eta_p^2 = .290$.

We explored the interaction via a series of posthoc t -tests employing a Bonferroni-adjusted α level of .0167 ($\alpha = .05 / 3$). For each test, Levene's test for equality of variances was significant, indicating that equal variances could not be assumed. The t -tests revealed that bilinguals outperformed the monolinguals in all conditions: neutral, $t(30.4) = 2.69, p = .012, d = .976$, opposite, $t(25.3) = 2.60, p = .015, d = 1.034$, but their advantage was greatest in the conflict condition, $t(22.3) = 4.68, p < .001, d = 1.982$. There was also a significant condition by age interaction, $F(2, 33) = 3.735, p = .035, \eta_p^2 = .185$. A follow-up analysis showed that this interaction was due to a significant correlation between children's age and their performance on the opposite, $r(37) = .386, p = .018$, but not the conflict, $r(37) = .132, p = .437$, or neutral, $r(37) = .107, p = .529$, Simon conditions.

<Insert Figure 2 about here>

Response time. Children's RTs for the neutral, opposite, and conflict Simon conditions are shown in Figure 2B. Data were screened for outliers and statistical assumptions were checked and deemed satisfactory. We conducted a $2 \times (3)$ ANCOVA on the children's RTs with the between-subjects factor of Group (monolinguals vs. bilinguals) and the within-subjects factor of Simon Condition (neutral vs. opposite vs. conflict). There was no main effect of group, $F(1, 34) = .501, p = .484, \eta_p^2 = .015$, but the effect of age was significant, $F(1, 34) = .29.080, p < .001, \eta_p^2 = .461$. Mauchly's test of sphericity was significant indicating that the sphericity assumption was violated, and thus we applied a Huynh-Feldt adjustment to the degrees of freedom. The main effect of Simon condition approached statistical significance, $F(1.74, 60.74) = 3.165, p = .055, \eta_p^2 = .161$, so it was explored via Sidak pairwise comparisons that revealed that, overall, children responded faster in the neutral condition than in the opposite, $p < .001$, or in the conflict conditions, $p < .001$,

and they also responded faster in the opposite condition than in the conflict condition, $p < .001$. There was no significant Group \times Simon Condition interaction, $F(1.74, 60.74) = 1.96$, $p = .155$, $\eta_p^2 = .053$. The interaction of age and Simon condition approached but did not reach statistical significance, $F(2, 33) = 3.122$, $p = .057$, $\eta_p^2 = .159$.

Congruent and incongruent trials within the Simon conflict condition.

Accuracy. Children's accuracy scores for the congruent and incongruent Simon conflict conditions are shown in Figure 3A. We conducted a $2 \times (2)$ ANCOVA on the children's accuracy scores with the between-subjects factor of Group (monolinguals vs. bilinguals) and the within-subjects factor of Conflict Condition (congruent vs. incongruent). A main effect of group, $F(1, 34) = 26.93$, $p < .001$, $\eta_p^2 = .442$, revealed that, overall, bilingual children performed better than monolinguals. There were no main effects of age, $F(1, 34) = 1.583$, $p = .217$, $\eta_p^2 = .042$, of conflict condition, $F(1, 34) = 1.609$, $p = .213$, $\eta_p^2 = .045$, and no significant Group \times Conflict Condition, $F(1, 34) = 3.130$, $p = .086$, $\eta_p^2 = .084$, and Age \times Conflict Condition interactions, $F(1, 34) = .275$, $p = .604$, $\eta_p^2 = .008$.

<Insert Figure 3 about here>

Response time. Children's RTs for the congruent and incongruent Simon conflict conditions are shown in Figure 3B. We conducted a $2 \times (2)$ ANCOVA on the children's RTs with the between-subjects factor of Group (monolinguals vs. bilinguals) and the within-subjects factor of Conflict Condition (congruent vs. incongruent). There was no significant main effect of group, $F(1, 34) = 0.113$, $p = .739$, $\eta_p^2 = .003$, but there was an effect of age, $F(1, 34) = 8.802$, $p = .005$, $\eta_p^2 = .206$. There was also no main effect of conflict condition, $F(1, 34) = 1.742$, $p = .196$, $\eta_p^2 = .049$, no significant Group \times Simon Condition, $F(1, 34) = .008$, $p = .930$, $\eta_p^2 < .001$, and no Age \times Simon Condition interaction, $F(1, 34) = 1.806$, $p = .188$, $\eta_p^2 = .050$.

Experiment 2

Participants

Forty young adult participants took part in Experiment 2. Twenty were monolingual speakers of Australian English (9 females, M age = 23.15 years, SD = 3.44; range 19 to 30 years), and 20 were bilingual speakers of Australian English and one additional language (14 females, M age = 22.55 years, SD = 3.36; range 19 to 29 years). All participants were undergraduate university students.

PPVT and EVT measures demonstrated that bilingual participants had significantly lower English receptive vocabulary scores and marginally lower expressive vocabulary scores than monolinguals (see Table 1). Participants also completed the Language Experience and Proficiency Questionnaire (LEAP-Q; Marian, Blumenfeld, & Kaushanskaya, 2007), which measures self-rated proficiency in understanding, speaking and writing, language and cultural exposure, and language usage in different daily surroundings. Responses to the LEAP-Q confirmed that all monolingual participants acquired English from birth and did not receive exposure to any additional language.

The bilingual participants were all native speakers of a language other than English, and had acquired English during childhood through immersion in an English community and formal education in English. Their age of English acquisition ranged from 4 to 13 years (M = 6.8 years, SD = 2.42). The additional languages were Mandarin (11), Cantonese (1), Arabic (1), Greek (1), Hindi (1), Fujian (1), Tibetan (1), and Dari (1). Participants' weekly exposure to English ranged from 30 to 90% (M = 56.25%, SD = 23.56). Participants were also asked to rate their English ability on a scale from 1 (low ability) to 10 (native-like ability). All bilingual young adults indicated that they had advanced to native-like proficiency in English speaking (M = 8.05, SD = 1.67), understanding (M = 8.2, SD = 1.51), and reading (M = 8.2, SD = 1.85).

Results

Verbal fluency tasks. Monolingual and bilingual young adults' performance was compared separately for each version of the VFT (see Figure 1). No significant group differences were observed for either the category VFT (monolingual $M = 24.85$, $SD = 6.49$; bilingual $M = 23.5$, $SD = 7.53$), $t(38) = .609$, $p = .547$, $d = .198$, or the letter VFT (monolingual $M = 16.05$, $SD = .8.47$; bilingual $M = 16.95$, $SD = 3.89$), $t(38) = -.432$, $p = .668$, $d = .140$.

Simon task.

Simon conditions.

Accuracy. Young adults' accuracy scores for the neutral, opposite, and conflict Simon conditions are shown in Figure 4A. Data were screened for outliers and statistical assumptions were checked. We conducted a $2 \times (3)$ ANOVA on the young adults' accuracy scores with the between-subjects factor of Group (monolinguals vs. bilinguals) and the within-subjects factor of Simon Condition (neutral vs. opposite vs. conflict). There was no significant main effect of group, $F(1, 38) = 0.19$, $p = .666$, $\eta_p^2 = .005$. There was a main effect of Simon condition, $F(2, 76) = 5.28$, $p = .010$, $\eta_p^2 = .122$. Sidak pairwise comparisons revealed that, overall, participants were more accurate in the neutral condition than in the opposite, $p = .05$, or in the conflict, $p = .028$, and that performance did not differ in the opposite and conflict conditions, $p = .961$. There was no significant Group \times Simon Condition interaction, $F(2, 76) = 0.411$, $p = .641$, $\eta_p^2 = .011$.

<Insert Figure 4 about here>

Response time. Young adults' RTs for the neutral, opposite, and conflict Simon conditions are shown in Figure 4B. Data were screened for outliers and statistical assumptions were checked. We conducted a $2 \times (3)$ ANOVA on the young adults' RTs with the between-subjects factor of Group (monolinguals vs. bilinguals) and the within-subjects

factor of Simon Condition (neutral vs. opposite vs. conflict). There was no significant main effect of group, $F(1, 38) = 1.39, p = .245, \eta_p^2 = .035$. There was a main effect of Simon condition, $F(2, 76) = 65.87, p < .001, \eta_p^2 = .634$. Sidak pairwise comparisons revealed that, overall, young adults responded faster in the neutral than in the opposite, $p < .001$, or in the conflict condition, $p < .001$, and they also responded faster in the opposite than in the conflict condition, $p < .001$. There was no significant Group \times Simon Condition interaction, $F(2, 76) = 1.66, p = .196, \eta_p^2 = .042$.

Congruent and incongruent trials within the Simon conflict conditions.

Accuracy. Young adults' accuracy scores for the congruent and incongruent Simon conflict conditions are shown in Figure 5A. We conducted a $2 \times (2)$ ANOVA on the young adults' accuracy scores with the between-subjects factor of Group (monolinguals vs. bilinguals) and the within-subjects factor of Conflict Condition (congruent vs. incongruent). There was no significant main effect of group, $F(1, 38) = 0.69, p = .413, \eta_p^2 = .018$. There was a main effect of conflict condition, $F(1, 38) = 9.61, p = .004, \eta_p^2 = .202$, showing that responses were more accurate in the congruent than the incongruent condition. There was no significant Group \times Conflict Condition interaction, $F(1, 38) = 0.44, p = .511, \eta_p^2 = .011$.

<Insert Figure 5 about here>

Response time. Young adults' RTs for the congruent and incongruent Simon conflict conditions are shown in Figure 5B. We conducted a $2 \times (2)$ ANOVA on the young adults' RTs with the between-subjects factor of Group (monolinguals vs. bilinguals) and the within-subjects factor of Conflict Condition (congruent vs. incongruent). There was no significant main effect of group, $F(1, 38) = 0.86, p = .771, \eta_p^2 = .002$. There was a main effect of conflict condition, $F(1, 38) = 7.67, p = .009, \eta_p^2 = .168$, indicating, similarly to the accuracy scores, that adults were faster in the congruent than the incongruent condition. There was no significant Group \times Simon Condition interaction, $F(1, 38) = 2.16, p = .150, \eta_p^2 = .054$.

Experiment 3

Participants

Thirty-five monolingual and bilingual older adults participated in Experiment 3. Eighteen were monolingual speakers of Australian English (9 females; M age = 69.06, SD = 6.54; range 60 to 81 years). Seventeen were bilingual speakers of Australian English and one additional language (13 females, M age = 67.71, SD = 8.1; range 56 to 80 years). The two groups did not differ in age, $t(33) = .544$, $p = .590$, $d = .189$. Participants were recruited through advertisements placed on a university campus and local community libraries.

PPVT and EVT measures demonstrated that bilingual participants had comparable English receptive vocabulary scores to monolinguals and marginally lower expressive vocabulary scores (see Table 1). Older adults also completed the LEAP-Q to report their levels of language proficiency and patterns of language use (see Experiment 2). LEAP-Q responses confirmed that all monolingual participants acquired English from birth and did not receive exposure to any additional language.

The bilingual participants were all native speakers of a language other than English, and had acquired English through immersion into an English community and/or formal education in English. Unlike the young adults in Experiment 2, older adults' age of English acquisition varied across the sample ($M = 10.5$ years, $SD = 7.84$). Two participants learned English from birth, 10 after starting primary school, and five as young adults. The additional languages were Italian (4), French (2), Hindi (2), German (2), Arabic (2), Croatian (2), Filipino (2), Czech (1), Lao (1), Malay (1), and Mandarin (1). Participants' weekly exposure to English ranged from 40 to 80% ($M = 62.36\%$, $SD = 1.48$). Participants were also asked to rate their English ability on a scale from 1 (low ability) to 10 (native-like ability). Bilingual older adults indicated that they had intermediate to native-like proficiency in English

speaking ($M = 6.94$, $SD = 1.89$), understanding ($M = 8.0$, $SD = 2.09$), and reading ($M = 7.47$, $SD = 1.91$).

Results

Verbal fluency tasks. Monolingual and bilingual older adults' performance was compared separately for each version of the VFT (see Figure 1). In this case, bilinguals ($M = 19.24$, $SD = 4.48$) produced significantly fewer words than monolinguals ($M = 23.11$, $SD = 6.26$) in the category VFT condition, $t(33) = 2.096$, $p = .044$, $d = .729$. On the other hand, monolinguals ($M = 16.89$, $SD = 5.96$) and bilinguals ($M = 14.47$, $SD = 5.01$) performed similarly on the letter VFT task, $t(33) = 1.295$, $p = .204$, $d = .451$.

Simon task.

Simon conditions.

Accuracy. Older adults' accuracy scores for the neutral, opposite, and conflict Simon conditions are shown in Figure 6A. We conducted a $2 \times (3)$ ANOVA on the older adults' accuracy scores with the between-subjects factor of Group (monolinguals vs. bilinguals) and the within-subjects factor of Simon Condition (neutral vs. opposite vs. conflict). There was no significant main effect of group, $F(1, 33) = 0.20$, $p = .655$, $\eta_p^2 = .006$. There was a main effect of Simon condition, $F(2, 66) = 7.07$, $p = .002$, $\eta_p^2 = .176$. Sidak pairwise comparisons revealed that, overall, older adults were more accurate in the neutral condition than in the opposite, $p = .004$, or in the conflict condition, $p = .003$, and that performance did not differ in the opposite and conflict conditions, $p = .983$. There was no significant Group \times Simon Condition interaction, $F(2, 66) = 0.03$, $p = .967$, $\eta_p^2 = .001$.

<Insert Figure 6 about here>

Response time. Older adults' RTs for the neutral, opposite, and conflict Simon conditions are shown in Figure 6B. We screened data and found one outlier, and this extreme RT was adjusted to one greater than the next most extreme score following the

recommendations of Tabachnick and Fidell (2013). All other statistical assumptions were deemed satisfactory. We conducted a $2 \times (3)$ ANOVA on the older adults' RTs with the between-subjects factor of Group (monolinguals vs. bilinguals) and the within-subjects factor of Simon Condition (neutral vs. opposite vs. conflict). A significant main effect of group, $F(1, 33) = 4.18, p = .049, \eta_p^2 = .112$, revealed that, overall, bilinguals responded faster than monolinguals ($M = 640$ vs. 771 ms). There was a main effect of Simon condition, $F(2, 66) = 8.77, p < .001, \eta_p^2 = .210$. Sidak pairwise comparisons revealed that, overall, older adults responded faster in the neutral condition than in the opposite, $p = .006$, or in the conflict condition, $p = .003$, and that RTs did not differ between the opposite and conflict conditions, $p = .898$. There was no significant Group \times Simon Condition interaction, $F(2, 66) = 0.62, p = .617, \eta_p^2 = .015$.

Congruent and incongruent trials within the Simon conflict conditions.

Accuracy. Older adults' accuracy scores for the congruent and incongruent Simon conflict conditions are shown in Figure 7A. We conducted a $2 \times (2)$ ANOVA on the older adults' accuracy scores with the between-subjects factor of Group (monolinguals vs. bilinguals) and the within-subjects factor of Conflict Condition (congruent vs. incongruent). There was no significant main effect of group, $F(1, 33) = 0.20, p = .654, \eta_p^2 = .006$. There was a main effect of conflict condition, $F(1, 33) = 7.54, p = .010, \eta_p^2 = .186$, with more accurate scores in the congruent than the incongruent condition. There was no significant Group \times Conflict Condition interaction, $F(1, 33) = 3.51, p = .070, \eta_p^2 = .096$.

<Insert Figure 7 about here>

Response time. Older adults' RTs for the congruent and incongruent Simon conflict conditions are shown in Figure 7B. We conducted a $2 \times (2)$ ANOVA on the older adults' RTs with the between-subjects factor of Group (monolinguals vs. bilinguals) and the within-subjects factor of Conflict Condition (congruent vs. incongruent). There was a significant

BILINGUALISM, VERBAL FLUENCY, AND EXECUTIVE FUNCTIONING

main effect of group, $F(1, 33) = 4.54, p = .041, \eta_p^2 = .121$, but there was no significant main effect of conflict condition, $F(1, 33) = 1.05, p = .312, \eta_p^2 = .031$, or Group \times Simon Condition interaction, $F(1, 33) = 0.025, p = .874, \eta_p^2 = .001$. We examined the bilingual group-level advantage via Bonferroni-adjusted posthoc t -tests that revealed that bilinguals outperformed the monolinguals in the incongruent condition, $t(33) = 2.77, p = .009, d = .964$, and the between-group difference in the congruent condition was marginally significant, $t(33) = 2.02, p = .051, d = .703$.

Discussion

The effects of bilingualism on cognitive processes outside the linguistic domain suggest that language and general cognitive abilities are integrated. In the case of bilinguals, it has been proposed that the experience of monitoring lexical access and suppressing one of their languages leads to simultaneous advantages in the non-verbal domain and disadvantages in the verbal domain (Bialystok, Craik, Green, & Gollan, 2009). However, this study adds to the growing evidence of a more complex relationship than was once thought by suggesting that bilingual non-verbal advantages and verbal disadvantages are moderated by individual differences in linguistic proficiency and developmental changes across the lifespan.

Effects of Bilingualism and Ageing on Executive Functioning

The present series of experiments employed the Simon Arrows task to assess executive functioning skills in monolinguals and bilinguals. A bilingual advantage was identified, but only for children and older adults (and not for young adults). Thus, these results confirm that the effects of bilingualism are most pronounced at the time points when executive functioning skills are undergoing developmental changes: boosting their development in childhood and attenuating their decline in older age (Bialystok et al., 2005).

The distinct conditions of the Simon Arrows task have been proposed to tap into distinct executive functioning components leading to the prediction that a bilingual advantage

BILINGUALISM, VERBAL FLUENCY, AND EXECUTIVE FUNCTIONING

should only be captured in the incongruent trials if its source lies in the bilingual experience of language monitoring and non-active language suppression (Gollan & Brown, 2006; Ivanova & Costa, 2008). However, a bilingual advantage was observed extending to the congruent and opposite trials as well as the incongruent trials. Thus, this result indicates that the bilingual experience rather leads to a global advantage in executive functioning and attentional skills that results in bilinguals' greater performance in trials that require them to provide a quick response both in the presence and absence of conflicting cues (Martin-Rhee & Bialystok, 2008). Accordingly, the effects of bilingualism on skills of attention monitoring and interference suppression are activated throughout the Simon Arrows task given that it requires participants to switch between trial types and selectively attend to different task rules (Costa et al., 2009). Thus, although the different trial types of the Simon Arrows task are designed to differentially target individual components of executive functioning, the combination of these trials used in this version of the task can trigger a bilingual advantage in incongruent trials as predicted, but also in congruent and opposite trials.

Effects of Bilingualism and Ageing on Verbal Fluency

Different performance patterns in verbal fluency were observed across the age groups included in this study. Monolingual and bilingual children performed similarly on category VFT, but bilinguals outperformed monolinguals on letter VFT. For the young adults, no performance differences were found in the two VFT tasks. On the contrary, bilingual older adults obtained lower scores than monolinguals on category VFT, but they did not differ from monolinguals in the letter VFT.

The results obtained in Experiment 1 replicate previous findings of a bilingual advantage in the letter VFT task among school-aged children (Friesen et al., 2015; Pino-Escobar et al., 2018). Crucially, such an advantage is proposed to only emerge among bilinguals who have comparable vocabulary scores to their monolingual peers, which was

BILINGUALISM, VERBAL FLUENCY, AND EXECUTIVE FUNCTIONING

also the case in this study. Even though bilingual children are often found to have smaller vocabulary sizes than monolinguals, bilinguals who acquire their two languages simultaneously or early in childhood and who receive extensive exposure to the target language (in this case English), including formal education, may develop an age-appropriate vocabulary size in this language that does not differ from monolinguals (McLeod, Castellanos-Ryan, Parent, Jacques, & Séguin, 2017).

However, when bilinguals have smaller vocabulary sizes in the target language, they tend to show lower performance than monolinguals on both category and letter VFTs, which has been attributed to lower lexical knowledge and weaker links established between the lexical items in the target language and their semantic representations (Gollan, Montoya, Cera, & Sandoval, 2008; Gollan, Montoya, Fennema-Notestine, & Morris, 2005). Bilingual younger adults in this study indeed had smaller English vocabularies than monolinguals, but their performance in category and letter VFTs was comparable. This suggests that even though VFTs rely on participants' lexical knowledge, it is not sufficient to account entirely for their ability to rapidly retrieve lexical items (Sullivan, Poarch, & Bialystok, 2018), and additional cognitive processes may support bilingual performance in this task (Friesen et al., 2015; Shao et al., 2014). Thus the lack of group differences in young adults' performance in both the Simon task and the two VFTs may not necessarily be an indicator of a lack of bilingualism effects. Instead, it is plausible that even though executive functions may be at their peak in young adulthood, thus masking behavioural group differences in the Simon task, the positive effects of bilingualism on executive functions may be detectable when linguistic processing is assessed (Luo et al., 2010).

Bilingual older adults showed a performance pattern that differed from both the children and young adults. Vocabulary differences in this age group were marginal, but bilinguals showed significantly poorer performance in the category VFT than monolinguals,

and there were no language group effects in the letter VFT. This result is in line with Roselli et al. (2000) who found a bilingual disadvantage in category but not letter VFT among older adults. In their study, language proficiency was assessed using the Boston Naming Test, and similarly to the present sample, bilinguals did not have significantly smaller vocabulary sizes than monolinguals. On the other hand, Bialystok et al. (2008a) found that bilingual older adults retrieved fewer words than monolinguals in both conditions of the VFT, but in their sample, monolinguals had significantly larger vocabulary sizes than bilinguals. Performance on the category VFT is associated primarily with lexical knowledge as this task resembles retrieval processes similar to everyday communication and does not engage additional interference suppression mechanisms (Levelt, 1999; Luo et al., 2010; Sandoval et al., 2010). However, in the case of bilinguals, it has been proposed that category VFT may impose an additional requirement on language monitoring and attentional processes. As the items are retrieved based on their semantic associations, this task is subject to greater interference from bilinguals' additional language. Therefore, difficulties in lexical retrieval associated with bilingualism may be more pronounced in older age and be more dependent on lexical competence. That is, when older bilinguals are highly proficient in the target language, the deficit emerges only in the semantic task as observed here, but when bilinguals' proficiency is lower than monolinguals', it may also affect the phonemic task (see Bialystok, Craik, & Luk, 2008b), potentially attenuating the protective function of bilinguals' advanced executive functioning skills.

When considering the effects of individual lexical competence on VFT performance, it must be noted that our study only included a VFT task in one of the bilinguals' languages. This is customary practice for samples of bilinguals from mixed linguistic backgrounds (e.g., Bialystok et al., 2008; Friesen et al., 2013; Pino-Escobar et al., 2018), and it allowed us to employ a single version of the VFT for all our monolingual and bilingual participants.

BILINGUALISM, VERBAL FLUENCY, AND EXECUTIVE FUNCTIONING

Furthermore, this decision was based on existing evidence that suggests that verbal fluency performance does not vary when assessed in both languages of a bilingual (Roselli et al., 2000). However, future data on participants' performance across languages are required to obtain a complete understanding of the interactions between aging and verbal fluency reported in this study.

An important factor that must be considered when interpreting the present findings is that our study included highly heterogeneous groups of bilingual participants. That is, our bilingual samples did not only differ in their first language and cultural backgrounds, but they also varied significantly in individuals' age of acquisition and patterns of exposure to each of their languages. All children in this study were born in a monolingual English community to parents who predominantly spoke a language other than English, and the children became immersed in English either from birth or after starting pre-school (around the age of three). On the other hand, the bilinguals in the young and the older adult groups learned English during childhood or early adulthood. Children and young adults received extensive exposure due to immersion in English at the time of testing, but there was significantly more variability in older adults' exposure to English. Age of acquisition and patterns of language use at the time of testing were not expected to impact performance in our tasks given that previous research has demonstrated that children (Carlson & Meltzoff, 2008; Kalashnikova & Mattock, 2014) and older adults (Bialystok et al., 2004, 2008a; Salvatierra & Rosselli, 2011) who are sequential bilinguals also exhibit a bilingual advantage compared to monolinguals in tasks of executive functioning. Furthermore, if it were the case that simultaneous bilingualism from birth or early childhood is a requirement for the manifestation of the bilingual advantage, we would expect the children and young adult bilinguals to outperform monolinguals, but not the older adults, which was not the case here. Indeed, via post-hoc

correlational analyses, we were able to confirm that these individual differences did not relate to performance in the Simon and VFT tasks (see Appendix).

Nevertheless, given that this study included conservative sample sizes and that the effect sizes for the group differences expected for these tasks tend to be in the small-to-medium range (Lehtonen et al., 2018), these sampling characteristics must be considered in the interpretation of the present findings (De Bruin, 2019). All participants in this study were recruited in an officially monolingual community, but which has become multilingual and multicultural due to immigration. As a result of changes in the immigration policies and other societal factors, immigration patterns have changed continuously across generations resulting in wide differences in individuals' countries of origin and age of arrival, and these differences are reflected in our community sample. The effects of bilingualism on general cognitive skills have been demonstrated across bilingual samples from different countries and linguistic backgrounds (e.g., Bialystok, Barac, Blaye, & Poulin-Dubois, 2010; Bialystok & Viswanathan, 2009; Yang, Yang, & Lust, 2011), but there is evidence that individual differences related to cultural background (Legare, Dale, Kim, & Deák, 2018; Luk & Bialystok, 2013), age of acquisition (Tao, Marzecová, Taft, Asanowicz, & Wodniecka, 2011), and patterns of language use (De Bruin, Bak, & Della Sala, 2015) may emerge in monolingual and bilingual performance in verbal and non-verbal tasks similar to the ones used here and may be particularly impactful when sampling small heterogeneous groups of bilingual participants.

Conclusion

This study assessed monolingual and bilingual performance in tasks of executive functioning and verbal fluency in children, young adults, and older adults. Our findings revealed that the effects of bilingual experience on performance in these non-verbal and verbal tasks were manifested differently in each age group. In the case of general executive

BILINGUALISM, VERBAL FLUENCY, AND EXECUTIVE FUNCTIONING

functioning, bilingual experience led to significant advantages but only at the time points when these skills were undergoing developmental changes (childhood, older adulthood). In the case of verbal processes, a bilingual advantage was only visible in children who outperformed monolinguals in the phonemic fluency task. The adult participants did not outperform monolinguals, but it is possible that their bilingual experience ameliorated the effects of the vocabulary deficits that typically lead to difficulties in lexical retrieval, but this positive effect of bilingualism was not observed in older adults. These findings provide further evidence that the effects of bilingual experience are manifested beyond the linguistic domain. However, their specific manifestation in linguistic and general executive functioning processes are moderated by the specific demands of each task, individual linguistic proficiency, and cognitive development across the lifespan.

References

- Adesope, O. O., Lavin, T., Thompson, T., & Ungerleider, C. (2010). A systematic review and meta-analysis of the cognitive correlates of bilingualism. *Review of Educational Research, 80*(2), 207-245.
- Antoniou, M. (2019). The Advantages of bilingualism debate. *Annual Review of Linguistics, 5*. doi:10.1146/annurev-linguistics-011718-011820
- Bak, T. H. (2016). The impact of bilingualism on cognitive ageing and dementia: finding a path through a forest of confounding variables. *Linguist Approaches to Bilingualism, 6* (1–2), 205–226.
- Barac, R., Moreno, S., & Bialystok, E. (2016). Behavioral and electrophysiological differences in executive control between monolingual and bilingual children. *Child development, 87*(4), 1277-1290.
- Bialystok, E. (2017). The bilingual adaptation: How minds accommodate experience. *Psychological Bulletin, 143*(3), 233-262. doi: 10.1037/bul0000099
- Bialystok, E., Barac, R., Blaye, A., & Poulin-Dubois, D. (2010). Word mapping and executive functioning in young monolingual and bilingual children. *Journal of Cognition and Development, 11*(4), 485-508.
- Bialystok, E., Craik, F. I., Green, D. W., & Gollan, T. H. (2009). Bilingual minds. *Psychological science in the public interest, 10*(3), 89-129.
- Bialystok, E., Craik, F. I. M., Klein, R., & Viswanathan, M. (2004). Bilingualism, aging, and cognitive control: Evidence from the Simon task. *Psychology and Aging, 19*(2), 290–303. doi: 10.1037/0882-7974.19.2.290
- Bialystok, E., Craik, F., & Luk, G. (2008a). Cognitive control and lexical access in younger and older bilinguals. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 34*(4), 859–873. doi: 10.1037/0278-7393.34.4.859

BILINGUALISM, VERBAL FLUENCY, AND EXECUTIVE FUNCTIONING

- Bialystok, E., Craik, F., & Luk, G. (2008b). Lexical access in bilinguals: Effects of vocabulary size and executive control. *Journal of Neurolinguistics*, *21*(6), 522–538. doi:10.1016/j.jneuroling.2007.07.001
- Bialystok, E., & Feng, X. (2009). Language proficiency and executive control in proactive interference: Evidence from monolingual and bilingual children and adults. *Brain and Language*, *109*(2-3), 93–100. doi:10.1016/j.bandl.2008.09.001
- Bialystok, E. & Feng, X. (2011). Language proficiency and its implications for monolingual and bilingual children. In A. Y. Durgunoglu & C. Goldenberg (eds.), *Language and literacy development in bilingual settings*, (pp. 121–138). New York: Guilford.
- Bialystok, E., Martin, M. M., & Viswanathan, M. (2005). Bilingualism across the lifespan: The rise and fall of inhibitory control. *International Journal of Bilingualism*, *9*(1), 103–119. doi: 10.1177/13670069050090010701
- Bialystok, E., Poarch, G., Luo, L., & Craik, F. I. (2014). Effects of bilingualism and aging on executive function and working memory. *Psychology and Aging*, *29*(3), 696–705. doi: 10.1037/a0037254
- Bialystok, E., & Viswanathan, M. (2009). Components of executive control with advantages for bilingual children in two cultures. *Cognition*, *112*(3), 494-500.
- Carlson, S. M., & Meltzoff, A. N. (2008). Bilingual experience and executive functioning in young children. *Developmental Science*, *11*(2), 282–298. doi: 10.1111/j.1467-7687.2008.00675.x
- Costa, A., Hernández, M., Costa-Faidella, J., & Sebastián-Gallés, N. (2009). On the bilingual advantage in conflict processing: Now you see it, now you don't. *Cognition*, *113*(2), 135–149. doi: 10.1016/j.cognition.2009.08.001

BILINGUALISM, VERBAL FLUENCY, AND EXECUTIVE FUNCTIONING

- Costa, A., Hernández, M., & Sebastián-Gallés, N. (2008). Bilingualism aids conflict resolution: Evidence from the ANT task. *Cognition*, *106*(1), 59–86. doi: 10.1016/j.cognition.2006.12.013
- Crivello, C., Kuzyk, O., Rodrigues, M., Friend, M., Zesiger, P., & Poulin-Dubois, D. (2016). The effects of bilingual growth on toddlers' executive function. *Journal of Experimental Child Psychology*, *141*, 121-132.
- De Bruin, A. (2019). Not all bilinguals are the same: A call for more detailed assessments and descriptions of bilingual experiences. *Behavioral Sciences*, *9*(33).
- De Bruin, A., Bak, T.H., Della Sala, S. (2015) Examining the effects of active versus inactive bilingualism on executive control in a carefully matched non-immigrant sample. *Journal of Memory and Language*, *85*, 15–26.
- De Bruin, A., Treccani, B., & Della Sala, S. (2015). Cognitive advantage in bilingualism: An example of publication bias? *Psychological Science*, *26*(1), 99–107. doi: 10.1177/0956797614557866
- Duñabeitia, J. A., Hernández, J. A., Antón, E., Macizo, P., Estévez, A., Fuentes, L. J., & Carreiras, M. (2014). The inhibitory advantage in bilingual children revisited. *Experimental Psychology*, *61*(3), 234-251. doi: 10.1027/1618-3169/a000243
- Dunn, L. M., & Dunn, D. M. (2007). *PPVT-4: Peabody picture vocabulary test*. Pearson Assessments.
- Esposito, A. G., Baker-Ward, L., & Mueller, S. T. (2013). Interference suppression vs. response inhibition: An explanation for the absence of a bilingual advantage in preschoolers' Stroop task performance. *Cognitive Development*, *28*(4), 354-363.
- Friesen, D. C., Luo, L., Luk, G., & Bialystok, E. (2015). Proficiency and control in verbal fluency performance across the lifespan for monolinguals and bilinguals. *Language, Cognition and Neuroscience*, *30*(3), 238–250. doi: 10.1080/23273798.2014.918630

BILINGUALISM, VERBAL FLUENCY, AND EXECUTIVE FUNCTIONING

- Gathercole, V. C. M., Thomas, E. M., Kennedy, I., Prys, C., Young, N., Viñas-Guasch, N., Roberts E., Hughes E., & Jones, L. (2014). Does language dominance affect cognitive performance in bilinguals? Lifespan evidence from preschoolers through older adults on card sorting, Simon, and metalinguistic tasks. *Frontiers in Psychology, 5*, 11. doi: 10.3389/fpsyg.2014.00011
- Green, D. W. (1998). Mental control of the bilingual lexico-semantic system. *Bilingualism: Language and cognition, 1*(2), 67-81.
- Gollan, T. H., & Acenas, L.-A. R. (2004). What Is a TOT? Cognate and Translation Effects on Tip-of-the-Tongue States in Spanish-English and Tagalog-English Bilinguals. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 30*(1), 246–269. doi: 10.1037/0278-7393.30.1.246
- Gollan, T. H., & Brown, A. S. (2006). From tip-of-the-tongue (TOT) data to theoretical implications in two steps: When more TOTs means better retrieval. *Journal of Experimental Psychology: General, 135*(3), 462–483. doi: 10.1037/0096-3445.135.3.462
- Gollan, T. H., & Kroll, J. F. (2001). Bilingual lexical access. In B. Rapp (Ed.), *The handbook of cognitive neuropsychology: What deficits reveal about the human mind* (pp. 321-345). New York, NY, US: Psychology Press.
- Gollan, T. H., Montoya, R. I., Cera, C., & Sandoval, T. C. (2008). More use almost always means a smaller frequency effect: Aging, bilingualism, and the weaker links hypothesis. *Journal of Memory and Language, 58*(3), 787-814. doi: 787–814. 10.1016/j.jml.2007.07.001
- Gollan, T. H., Montoya, R. I., Fennema-Notestine, C., & Morris, S. K. (2005). Bilingualism affects picture naming but not picture classification. *Memory & Cognition, 33*(7), 1220–1234. doi: 10.3758/BF03193224

BILINGUALISM, VERBAL FLUENCY, AND EXECUTIVE FUNCTIONING

- Gollan, T. H., Montoya, R. I., & Werner, G. A. (2002). Semantic and letter fluency in Spanish-English bilinguals. *Neuropsychology, 16*(4), 562–576. doi: 10.1037/0894-4105.16.4.562
- Ivanova, I., & Costa, A. (2008). Does bilingualism hamper lexical access in speech production? *Acta Psychologica, 127*(2), 277–288. doi: 10.1016/j.actpsy.2007.06.003
- Kalashnikova, M., & Mattock, K. (2014). Maturation of executive functioning skills in early sequential bilingualism. *International Journal of Bilingual Education and Bilingualism, 17*(1), 111-123.
- Kousaie, S., Sheppard, C., Lemieux, M., Monetta, L., & Taler, V. (2014). Executive function and bilingualism in young and older adults. *Frontiers in Behavioral Neuroscience, 8*, 250. doi: 10.3389/fnbeh.2014.00250
- Kovács, Á. M., & Mehler, J. (2009). Cognitive gains in 7-month-old bilingual infants. *Proceedings of the National Academy of Sciences*, pnas-0811323106.
- Kovács, Á. M., & Mehler, J. (2009). Flexible learning of multiple speech structures in bilingual infants. *Science, 325*(5940), 611-612.
- Kroll, J. F., & Bialystok, E. (2013). Understanding the Consequences of Bilingualism for Language Processing and Cognition. *Journal of Cognitive Psychology, 25*(5). doi:10.1080/20445911.2013.799170
- Kroll, J. F., Gollan, T. H., Goldrick, M., Ferreira, V., & Miozzo, M. (2014). Speech planning in two languages: What bilinguals tell us about language production. *The Oxford handbook of language production*, 165-181.
- Legare, C. H., Dale, M. T., Kim, S. Y., & Deák, G. O. (2018). Cultural variation in cognitive flexibility reveals diversity in the development of executive functions. *Scientific Reports, 8*(1), 16326.

BILINGUALISM, VERBAL FLUENCY, AND EXECUTIVE FUNCTIONING

- Lehtonen, M., Soveri, A., Laine, A., Järvenpää, J., de Bruin, A., & Antfolk, J. (2018). Is bilingualism associated with enhanced executive functioning in adults? A meta-analytic review. *Psychological Bulletin*, *144*(4), 394.
- Levelt, W. J. (1999). Models of word production. *Trends in Cognitive Sciences*, *3*(6), 223–232. doi: 10.1016/S1364-6613(99)01319-4
- Luk, G., & Bialystok, E. (2013). Bilingualism is not a categorical variable: Interaction between language proficiency and usage. *Journal of Cognitive Psychology*, *25*(5), 605–621.
- Luo, L., Luk, G., & Bialystok, E. (2010). Effect of language proficiency and executive control on verbal fluency performance in bilinguals. *Cognition*, *114*(1), 29–41. doi: 10.1016/j.cognition.2009.08.014
- Martin-Rhee, M. M., & Bialystok, E. (2008). The development of two types of inhibitory control in monolingual and bilingual children. *Bilingualism: Language and Cognition*, *11*(1), 81–93. doi: 10.1017/S1366728907003227
- McLeod, S., Crowe, K., Masso, S., Baker, E., McCormack, J., Wren, Y., Roulstone S., & Howland, C. (2017). Profile of Australian preschool children with speech sound disorders at risk for literacy difficulties. *Australian Journal of Learning Difficulties*, *22*(1), 15–33. doi: 10.1080/19404158.2017.1287105
- Michael, E. B., & Gollan, T. H. (2005). Being and Becoming Bilingual: Individual Differences and Consequences for Language Production. In J. F. Kroll & A. M. B. de Groot (Eds.), *Handbook of bilingualism: Psycholinguistic approaches* (pp. 389–407). New York, NY, US: Oxford University Press.
- Oller, D. K., & Eilers, R. E. (Eds.). (2002). *Language and literacy in bilingual children* (Vol. 2). Clevedon, UK: Multilingual Matters.

BILINGUALISM, VERBAL FLUENCY, AND EXECUTIVE FUNCTIONING

- Paap, K. R., Johnson, H. A., & Sawi, O. (2015). Bilingual advantages in executive functioning either do not exist or are restricted to very specific and undetermined circumstances. *Cortex*, *69*, 265–278. doi: 10.1016/j.cortex.2015.04.014
- Pearson, B. Z., Fernandez, S. C., Lewedeg, V., & Oller, D. K. (1997). The relation of input factors to lexical learning by bilingual infants. *Applied Psycholinguistics*, *18*(1), 41-58.
- Perret, E. (1974). The left frontal lobe of man and the suppression of habitual responses in verbal categorical behaviour. *Neuropsychologia*, *12*(3), 323–330. doi: 10.1016/0028-3932(74)90047-5
- Pino-Escobar, G. P., Kalashnikova, M., & Escudero, P. (2018). Vocabulary matters! The relationship between verbal fluency and measures of inhibitory control in monolingual and bilingual children. *Journal of Experimental Child Psychology*, *170*, 177–189. doi: 10.1016/j.jecp.2018.01.012
- Portocarrero, J. S., Burright, R. G., & Donovanick, P. J. (2007). Vocabulary and verbal fluency of bilingual and monolingual college students. *Archives of Clinical Neuropsychology*, *22*(3), 415–422. doi: 10.1016/j.acn.2007.01.015
- Roberts, P. M., Garcia, L. J., Desrochers, A., & Hernandez, D. (2002). English performance of proficient bilingual adults on the Boston Naming Test. *Aphasiology*, *16*(4–6), 635–645. doi: 10.1080/02687030244000220
- Rosselli, Mónica, Ardila, A., Araujo, K., Weekes, V. A., Caracciolo, V., Padilla, M., & Ostrosky-Solí, F. (2000). Verbal fluency and repetition skills in healthy older Spanish-English bilinguals. *Applied Neuropsychology*, *7*(1), 17–24. doi: 10.1207/S15324826AN0701_3
- Rosselli, Monica, Ardila, A., Salvatierra, J., Marquez, M., Luis, M., & Weekes, V. A. (2002). A cross-linguistic comparison of verbal fluency tests. *International Journal of Neuroscience*, *112*(6), 759–776. doi: 10.1080/00207450290025752

BILINGUALISM, VERBAL FLUENCY, AND EXECUTIVE FUNCTIONING

- Sabourin, L., Leclerc, J.-C., Lapierre, M., Burkholder, M., & Brien, C. (2016). The language background questionnaire in L2 research: Teasing apart the variables. In *Annual Meeting of the Canadian Linguistics Association, Calgary, Canada*.
- Salvatierra, J., & Rosselli, M. (2011). The effect of bilingualism and age on inhibitory control. *International Journal of Bilingualism, 15*(1), 26–37. doi: 10.1177/1367006910371021
- Sandoval, T.C., Gollan, T.H., Ferreira, V.S., & Salmon, D.P. (2010). What causes the bilingual disadvantage in verbal fluency: The dual-task analogy. *Bilingualism: Language and Cognition, 13*, 231-252.
- Schmidt, C. S., Schumacher, L. V., Römer, P., Leonhart, R., Beume, L., Martin, M., Dressing A., Weiller C, & Kaller, C. P. (2017). Are semantic and phonological fluency based on the same or distinct sets of cognitive processes? Insights from factor analyses in healthy adults and stroke patients. *Neuropsychologia, 99*, 148–155. doi: 10.1016/j.neuropsychologia.2017.02.019
- Schneider, W., Eschman, A., & Zuccolotto, A. (2002). *E-Prime: User's guide*. Psychology Software Incorporated.
- Shao, Z., Janse, E., Visser, K., & Meyer, A. S. (2014). What do verbal fluency tasks measure? Predictors of verbal fluency performance in older adults. *Frontiers in Psychology, 5*, 772. doi: 10.3389/fpsyg.2014.00772
- Sorge, G. B., Toplak, M. E., & Bialystok, E. (2017). Interactions between levels of attention ability and levels of bilingualism in children's executive functioning. *Developmental science, 20*(1), e12408.
- Strauss, E., Sherman, E. M.S., & Spreen, O. (2006). A compendium of neuropsychological tests: Administration, norms, and commentary (3rd ed.). New York: Oxford University Press.

BILINGUALISM, VERBAL FLUENCY, AND EXECUTIVE FUNCTIONING

- Sullivan, M. D., Poarch, G. J., & Bialystok, E. (2018). Why is lexical retrieval slower for bilinguals? Evidence from picture naming. *Bilingualism: Language and Cognition*, 21(3), 479–488. doi:10.1017/S1366728917000694
- Tabachnick, B. G., & Fidell, L. S. (2013). *Using multivariate statistics* (6th ed.). Boston: Pearson.
- Tao, L., Marzecová, A., Taft, M., Asanowicz, D., & Wodniecka, Z. (2011). The efficiency of attentional networks in early and late bilinguals: The role of age of acquisition. *Frontiers in Psychology*, 2, 123.
- Tran, C. D., Arredondo, M. M., & Yoshida, H. (2015). Differential effects of bilingualism and culture on early attention: A longitudinal study in the US, Argentina, and Vietnam. *Frontiers in psychology*, 6, 795.
- Yang, S., & Yang, H. (2016). Bilingual effects on deployment of the attention system in linguistically and culturally homogeneous children and adults. *Journal of experimental child psychology*, 146, 121-136.
- Yang, S., Yang, H., & Lust, B. (2011). Early childhood bilingualism leads to advances in executive attention: Dissociating culture and language. *Bilingualism: Language and Cognition*, 14(3), 412-422.
- Williams, K. T. (1997). *Expressive Vocabulary Test*. Circle Pines, MN: American Guidance Service.

BILINGUALISM, VERBAL FLUENCY, AND EXECUTIVE FUNCTIONING

Table 1. Monolingual and bilingual English receptive (PPVT) and Expressive (EVT) English vocabulary mean (SD) scores for children, young adults, and older adults.

		Monolingual	Bilingual	<i>t</i> -test
Children (Expt. 1)	Receptive	107.00 (13.56)	114.05 (17.59)	$t(35) = -1.346, p = .187$
	Expressive	105.59 (14.94)	110.65 (18.32)	$t(35) = -0.910, p = .369$
Young adults (Expt. 2)	Receptive	98.55 (9.39)	86.75 (13.11)	$t(38) = 3.272, p = .002$
	Expressive	100.4 (10.32)	92.7 (15.5)	$t(38) = 1.849, p = .072$
Older adults (Expt. 3)	Receptive	109.11 (12.84)	102.53 (15.93)	$t(33) = 1.350, p = .196$
	Expressive	112.39 (11.64)	103.12 (15.98)	$t(33) = 1.970, p = .057$

List of Figures

Figure 1. Mean number of words produced by monolingual and bilingual children (Experiment 1), young adults (Experiment 2), and older adults (Experiment 3) in the category and letter verbal fluency tasks (VFT). Error bars represent SEM.

Figure 2. Accuracy scores (A) and response times (B) for monolingual and bilingual children in neutral, opposite, and conflict Simon conditions. Error bars represent SEM.

Figure 3. Accuracy scores (A) and response times (B) for monolingual and bilingual children in congruent and incongruent Simon conflict conditions. Error bars represent SEM.

Figure 4. Accuracy scores (A) and response times (B) for monolingual and bilingual young adults in neutral, opposite, and conflict Simon conditions. Error bars represent SEM.

Figure 5. Accuracy scores (A) and response times (B) for monolingual and bilingual young adults in congruent and incongruent Simon conflict conditions. Error bars represent SEM.

Figure 6. Accuracy scores (A) and response times (B) for monolingual and bilingual older adults in neutral, opposite, and conflict Simon conditions. Error bars represent SEM.

Figure 7. Accuracy scores (A) and response times (B) for monolingual and bilingual older adults in congruent and incongruent Simon conflict conditions. Error bars represent SEM.

BILINGUALISM, VERBAL FLUENCY, AND EXECUTIVE FUNCTIONING

Appendix

Table A1. Results of correlational analyses between English exposure (average percentage of weekly exposure), and the VFT and Simon Task performance for children, young adults, and old adults in our study.

	VFT		Simon Task (Accuracy/RT)				
	Letter	Category	Neut.	Conf.	Opp.	Cong.	Incong.
Children	-.057	-.028	.270/ -.055	.460/ .215	.290/ -.155	.063/ -.261	.053/ -.205
Young adults	-.048	.183	-.148/ -.034	-.318/ .160	-.278/ -.036	-.254/ -.139	-.322/ -.180
Old adults	.186	-.082	.232/ .035	.211/ -.196	.119/ .071	.232/ .023	.064/ .045

Table A2. Results of correlational analyses between Age of Acquisition (AoA), and the VFT and Simon Task performance for children, young adults, and old adults in our study.

	VFT		Simon Task (Accuracy/RT)				
	Letter	Category	Neut.	Conf.	Opp.	Cong.	Incong.
Children	-.252	-.240	-.206/ .052	-.547*/ -.002	-.007/ -.062	-.341/ -.059	-.548*/ .171
Young adults	.178	-.098	-.044/ .006	.330/ .087	.393/ .016	.408/ .001	.173/ .186
Old adults	-.256	-.329	-.212/ -.061	.199/ .071	-.223/ -.045	-.447/ -.001	-.233/ -.070

$p < .05$