The effect of bilingualism and age on inhibitory control

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Abstract
Bilingualism may provide an advantage to older adults on inhibitory control tasks. This study examined the effects of bilingualism (balanced and non-balanced) on inhibitory control using simple and complex Simon tasks with samples of younger and older Spanish–English bilinguals (N = 125) and English monolinguals (N = 108). Results revealed a bilingual advantage on the simple task but not on the complex Simon task. Results suggest that bilingualism increases skills that are associated with selective attention when working memory demands are low.

Keywords
aging inhibitory control, bilingualism, executive functions, language, Spanish

1. Introduction
Evidence regarding effects of bilingualism on cognition has been mixed. Some early research suggested that bilingualism may have detrimental effects on intelligence and language development (Tucker & d’Anglejan, 1971); some studies have found no difference between bilinguals and monolinguals (Rosenblum & Pinker, 1983); and others have observed a cognitive advantage for bilinguals over monolinguals including an increase in mental flexibility (Cummins, 1976), superior performance on tasks requiring selective attention (Bialystok, 1999), greater diversity of cognitive strategies (Ben-Zeev, 1977), and higher metalinguistic awareness (Cummins, 1978).

The most recent research typically finds positive effects of bilingualism on cognitive processes (Bialystok, Craik, & Freedman, 2007; Kave, Eyal, Shorek, & Cohen-Mansfield, 2008) particularly on executive control functions (Bialystok, Craik, Klein, & Viswanathan, 2004; Bialystok, Craik, & Ryan, 2006). For example, there seems to be an advantage for bilinguals when performing an inhibitory task like the visual Simon task (Bialystok et al., 2004).

The findings reported by Bialystok et al. (2004), however, have not always been replicated and remain controversial (e.g. Colzato et al., 2008; Costa, Hernández, Costa-Faidella, & Sebastián-Gallés,
Moreover, the studies that have demonstrated a bilingual advantage examined individuals who were proficient in both of their languages, and it is still unclear how the level of bilingualism interacts with this advantage. Gollan, Fennema-Notestine, Montoya, and Jernigan (2007) found that degree of bilingualism has an important effect on a confrontation naming task, and it is reasonable to think that it may have an influence on inhibition tasks as well.

The present study attempted to further investigate the influence of bilingualism on inhibitory control using Simon tasks with two groups of bilinguals who differed in language experience (balanced and non-balanced) and including a larger sample than the one used by previous studies (e.g. Bialystok et al., 2004). It was hypothesized that the performance of bilingual groups would be better than the performance of monolinguals on the Simon task since controlled processing in bilinguals seems to be more effective (Bialystok et al., 2004). Moreover, a greater advantage for the balanced bilinguals over the non-balanced was anticipated. If the balanced bilinguals have a smaller Simon effect than the non-balanced bilinguals it will suggest that bilingual proficiency per se enhances inhibitory control. If no differences are found between the bilingual groups, it may suggest that other variables associated with bilingualism (i.e. frequency of switching between languages) explains the bilingual advantage. In addition, it was expected that the bilingual advantage would become more evident under a more complex condition of the Simon task involving greater working memory demand. If this holds true, it will imply that the continuous control of two languages has an extended effect over control and effortful executive process. If the bilingual advantage is seen only in the simple condition, it will suggest that the effects of bilingualism are more limited to automatic switching processes.

2. Method

2.1 Participants

Participants consisted of 108 monolinguals and 125 bilinguals. Younger participants were college students, older participants were their family members and friends. All participants were South Florida residents. All individuals reported no antecedent-cardiovascular, psychiatric or neurological disease and all of them reported good health. Every one of the older adults lived independently. All participants reported normal or corrected-to-normal visual acuity and were able to clearly distinguish between the colors used in the Simon task. Younger participants received extra credit points in a psychology course for their participation in the study; the older participants received a $10.00 gift card. There were no significant differences in age, $F(1,131) = 0.489, p = 0.485$, or years of education, $F(1,131) = 1.520, p = 0.220$, between the younger monolingual and bilingual participants, or in age, $F(1,98) = 0.125, p = 0.724$, or years of education, $F(1,98) = 1.592, p = 0.210$, between the older monolingual and bilingual participants.

To ensure equivalent non-verbal cognitive capacities, all participants were required to score 7 (no more than 1 SD below the mean, which was 10) on the Block Design subtest from the Wechsler Adult Intelligence Scale III (Wechsler, 1997). This test is considered one the best measures of visuospatial organization (Lezak, Howieson, & Loring, 2004). There were no between-group differences on this test, $F(3,228) = 1.007, p = 0.390$.

2.2 Assessment of bilingualism

To determine language history and degree of bilingualism, participants provided information about language usage while growing up, recent language use, language preference, age of second language
acquisition, and their means of acquiring their second language. The bilingual participants also completed a five-point rating scale on how well they understood and spoke each of their two languages (Rosselli et al., 2000; Rosselli et al., 2002). Significant correlations between self-rating questionnaires of language proficiency and actual language proficiency have been previously reported (Hakuta, Bialystok, & Wiley, 2003). Only participants that rated themselves as able to understand and speak both Spanish and English ‘relatively well’, ‘quite well’, or ‘excellently’ were selected.

The Boston Naming Test – BNT – (Kaplan, Goodglass, & Weintraub, 1983, 1996) was administered to screen for naming proficiency in English. Bilingual participants were administered the Spanish version of the test as well in order to screen for naming proficiency in Spanish. The performance of the younger and older bilinguals was poorer than the performance of their monolingual counterparts – \( F(1,131) = 20.770, p < 0.001 \), for the younger individuals; \( F(1,98) = 16.585, p < 0.001 \), for the older individuals. However, there were no differences in scores between the younger and older monolinguals, \( F(1,106) = 0.017, p = 0.896 \), or between the younger and older bilinguals, \( F(1,123) = 0.569, p = 0.452 \). The previously reported bilingual disadvantage in the English BNT (i.e. Gollan et al., 2007; Rosselli et al., 2000) was almost equal for the young and old groups, and no significant interaction was observed between language group and age \( F(1,232) = 0.40, p = 0.52 \). General characteristics of the sample are presented in Table 1.

The English and Spanish versions of the BNT were also used to distinguish between balanced and non-balanced bilinguals. Bilingual participants with a difference between the two BNT scores (English and Spanish) equal to or lower than the group median (11 points) were considered balanced bilinguals. The balanced bilinguals (\( N = 69 \)) significantly differed from the non-balanced (\( N = 56 \)) on the language proficiency questionnaire, \( F(1,123) = 9.88, p = 0.002 \). They did not differ in age, \( F(1,123) = 0.94, p = 0.33 \), years of education, \( F(1,123) = 0.181, p = 0.67 \), nor in scores on the WAIS-III Block Design subtest \( F(1,123) = 1.20, p = 0.27 \). All bilinguals reported daily use of both languages; the two groups differed on the relative of use of each language. For example, whereas 88 per cent of the balanced bilinguals reported using English and Spanish equally frequently, only 59 per cent of the non-balanced group reported equal use of both languages. The specific characteristics of the bilingual groups are presented in Table 2.

### Table 1. Mean demographic characteristics (and the standard deviation) of the four groups. The language characteristics of the bilingual sample are also included

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Younger Monolingual (n = 66)</th>
<th>Bilingual (n = 67)</th>
<th>Older Monolingual (n = 42)</th>
<th>Bilingual (n = 58)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>25.88 (6.4)</td>
<td>26.67 (6.6)</td>
<td>63.40 (8.4)</td>
<td>64.84 (7.3)</td>
</tr>
<tr>
<td>Years of education</td>
<td>16.67 (2.4)</td>
<td>16.09 (3.0)</td>
<td>14.93 (2.6)</td>
<td>15.26 (2.8)</td>
</tr>
<tr>
<td>Block design (scaled score)</td>
<td>10.50 (2.6)</td>
<td>11.22 (2.4)</td>
<td>10.93 (2.9)</td>
<td>11.26 (2.8)</td>
</tr>
<tr>
<td>BNT (English)</td>
<td>51.82 (5.9)</td>
<td>45.36 (9.9)</td>
<td>52.02 (10.4)</td>
<td>44.07 (9.1)</td>
</tr>
<tr>
<td>Age of L2 acquisition</td>
<td>11.00 (7.0)</td>
<td></td>
<td>19.74 (15.7)</td>
<td></td>
</tr>
<tr>
<td>English BNT</td>
<td>45.36 (9.9)</td>
<td></td>
<td>44.07 (9.1)</td>
<td></td>
</tr>
<tr>
<td>Spanish BNT</td>
<td>44.63 (8.5)</td>
<td></td>
<td>51.31 (6.0)</td>
<td></td>
</tr>
<tr>
<td>Understand L2</td>
<td>4.69 (.53)</td>
<td></td>
<td>4.05 (.92)</td>
<td></td>
</tr>
<tr>
<td>Speak L2</td>
<td>4.30 (.80)</td>
<td></td>
<td>3.98 (.87)</td>
<td></td>
</tr>
<tr>
<td>Understand L1</td>
<td>4.79 (.45)</td>
<td></td>
<td>4.84 (.45)</td>
<td></td>
</tr>
<tr>
<td>Speak L1</td>
<td>4.64 (.62)</td>
<td></td>
<td>4.81 (.48)</td>
<td></td>
</tr>
</tbody>
</table>
2.3 Inhibitory control task

A Simon task designed to measure inhibitory control was administered to all participants. The stimuli were presented on a computer screen. Participants performed under two conditions. 1. Simple condition: A series of squares that were either green or red appeared on either the left or right side of a computer screen. Participants pressed the left shift key when green squares appeared and the right shift key when red appeared. The order of the trials was randomized. There were equal numbers of congruent (the stimulus and the correct response key are located on the same side) and incongruent (the stimulus and the correct response key are located on opposite sides) trials. The location of the stimulus was the distracter. 2. Complex condition: This condition was similar to the simple condition except that the stimuli consisted of four different colored squares instead of two. Blue, yellow, purple, and white squares appeared on either the left or right side of the computer screen. Participants were instructed to press the left shift key when either a blue or yellow square appeared and the right shift key when either a purple or white square appeared. Once again, the order of the trials was randomized. There were also equal numbers of congruent and incongruent trials. The location of the stimulus was the distracter.

The sequencing of trials and the collection of the data were controlled by a program running on DMDX. DMDX is a Win 32-based display system developed by Forster and Forster (2003). Each stimulus was presented for 800 ms, while the interstimulus interval was 250 ms. Reaction time to correct responses was the dependent measure. The statistical analyses were done with reaction times (RTs) and z-scores transformations (see later in this article). Practice trials preceded each condition. Participants were required to complete each practice trial set correctly before being able to continue with testing. The items of the Simon task consisted of two parts; each included 24 items from the simple condition and 24 of the complex condition. The second part contained the same items as the first part but was administered in the reverse order. The presentation of the simple and complex condition was counterbalanced.

Responses made by pressing the incorrect computer key or a lack of response (not pressing a key) were considered errors. The percentage of incorrect responses in each condition was the error rate. Only correct responses were used for the analyses.
2.4 Procedure

Participants were first contacted by phone, and an initial screening interview was conducted to determine if the person was monolingual or bilingual. An informed consent in accordance with APA Ethical Guidelines for research with human subjects was obtained from all participants.

The testing session began with the first part of the Simon task followed by the completion of the language background questionnaire. Participants then completed the second part of the Simon task and the Block Design. Individuals who scored below 7 did not receive further testing. Three monolinguals and two bilinguals were excluded. Monolingual participants then completed the English BNT; half of the bilingual participants proceeded with the English BNT and half with the Spanish BNT. Bilingual participants concluded the testing session with the remaining version of the BNT (English or Spanish).

2.5 Statistical procedures

To control for the general slowing associated with age, transformations into $z$ scores were used (Faust, Balota, Spieler, & Ferraro, 1999): (1) computation of an overall mean RT and an overall SD (collapsing across all conditions); (2) for each trial a $z$ score was computed by subtracting the overall mean and dividing by the overall standard deviation; (3) for each condition, the $z$ scores were summed and the average $z$ scores were computed and (4) the incongruent minus congruent scores were computed as the indices of inhibitory control (Simon effect).

Effects of language group, age group and task on the Simon effect $z$ scores were tested in a 2 (monolingual, bilingual) $\times$ 2 (older, young) $\times$ 2 (simple, complex) mixed ANOVA. To further investigate the mean differences between the two bilingual groups from different age groups, one-way ANOVAs were calculated. The effect sizes were assessed using partial eta² ($\eta^2$) for overall group differences.

3. Results

Table 3 shows the reaction times and the $z$ score transformation and standard deviations for the correct responses to congruent and incongruent trial, plus the Simon effect by groups. $Z$ scores in the simple condition are negative because RTs were faster than those registered in the congruent and incongruent trials on the complex condition.

3.1 Bilingual vs. monolinguals

Main effects. The comparison of the Simon effect of younger and older monolingual and bilingual participants revealed that the effect of language group was significant, $F(1,229) = 4.02, p = 0.046, \eta^2 = 0.02$. Monolingual participants had a mean Simon effect $z$ score of 0.29 (SD = 0.37); bilingual participants had a mean Simon effect $z$ score of 0.21 (SD = 0.38) (see Table 2). Also there was a significant effect of age, $F(1,229) = 7.80, p = 0.006, \eta^2 = 0.03$; older participants’ Simon effect $z$ score was 0.32 (SD = 0.45) while younger participants’ $z$ score was 0.19 (SD = 0.30). The main effect of complexity was also significant, $F(1,229) = 50.25, p < 0.001, \eta^2 = 0.18$. The Simon effect in the complex condition ($z = 0.10, SD = 0.54$) was significantly smaller than the same effect in the simple condition, ($z = 0.39, SD = 0.47$), $F(1,232) = 44.27, p < 0.001, \eta^2 = 0.16$. However, the Simon effect in the complex condition is statistically significant since the difference between the $z$ scores in the incongruent (mean $z$ score = 0.48, SD = 1.22) and congruent trials (mean $z$ score = 0.37,
No significant interaction was found between age and language group across conditions, $F(1,229) = 1.06, p = 0.30, \eta^2_p = 0.005$. However a significant interaction between age and language was found for the simple condition, $F(1,229) = 5.88, p = 0.016, \eta^2_p = 0.02$. Older and younger bilinguals did not differ in Simon effect, $F(1,123) = 0.76, p = 0.78, \eta^2_p = 0.001$, but this difference was significant in the monolingual group, $F(1,106) = 10.93, p = 0.001, \eta^2_p = 0.09$. The multivariate main effects revealed a significant interaction between language group and complexity, $F(1,229) = 8.84, p = 0.003, \eta^2_p = 0.03$ with the Simon effect $z$ score differences between the language groups found in the simple condition only and for the older group. Whereas young bilinguals did not show a significantly smaller Simon effect than monolinguals in the simple condition, $F(1,132) = 1.63, p = 0.20$, older bilinguals did, $F(1,132) = 12.32, p = 0.001$. These two interactions were also significant using RTs (Age X language group, simple condition, $F(1,229) = 5.88, p = 0.016, \eta^2_p = 0.02$; Language group X complexity, $F(1,229) = 4.64, p = 0.032, \eta^2_p = 0.02$). Separate two-way analyses of variance of each condition on the Simon task revealed that under the simple condition of the Simon task, the main effect of language group was significant, $F(1,229) = 14.53, p < 0.001, \eta^2_p = 0.06$ with the bilinguals having a smaller Simon effect ($z$ score = 0.30, SD = 0.42) than the monolinguals ($z$ score = 0.50, SD = 0.50). However, there was not a significant difference in the Simon effect $z$ scores between the two language groups under the complex condition, $F(1,229) = 0.15, p = 0.69, \eta^2_p = 0.001$. The mean Simon $z$ scores for the bilinguals was 0.12

Table 3. Mean reaction times (and Standard Deviations) in milliseconds and $Z$ scores transformations by age and language groups

<table>
<thead>
<tr>
<th>Language group</th>
<th>Condition</th>
<th>Congruent</th>
<th>Incongruent</th>
<th>Simon Effect (z scores)</th>
<th>Accuracy (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Younger</td>
<td>Monolingual Simple (RT, ms)</td>
<td>433.98 (70.5)</td>
<td>470.99 (63.9)</td>
<td>37.54 (33.3)</td>
<td>93.91</td>
</tr>
<tr>
<td></td>
<td>Complex (RT, ms)</td>
<td>521.18 (70.0)</td>
<td>527.37 (73.7)</td>
<td>6.19 (37.4)</td>
<td>91.86</td>
</tr>
<tr>
<td></td>
<td>Simple (z scores)</td>
<td>-0.882 (0.73)</td>
<td>-0.501 (0.67)</td>
<td>0.381 (0.35)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Complex (z scores)</td>
<td>0.025 (0.73)</td>
<td>0.090 (0.77)</td>
<td>0.064 (0.39)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Bilingual Simple (RT in ms)</td>
<td>451.42 (64.7)</td>
<td>480.40 (70.5)</td>
<td>29.41 (39.7)</td>
<td>94.62</td>
</tr>
<tr>
<td></td>
<td>Complex (RT in ms)</td>
<td>539.24 (81.6)</td>
<td>544.04 (86.1)</td>
<td>4.79 (40.8)</td>
<td>92.48</td>
</tr>
<tr>
<td></td>
<td>Simple (z scores)</td>
<td>-0.700 (0.67)</td>
<td>-0.403 (0.74)</td>
<td>0.297 (0.42)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Complex (z scores)</td>
<td>0.213 (0.85)</td>
<td>0.263 (0.90)</td>
<td>0.050 (0.42)</td>
<td></td>
</tr>
<tr>
<td>Older</td>
<td>Monolingual Simple (RT in ms)</td>
<td>470.45 (67)</td>
<td>537.35 (87.8)</td>
<td>66.90 (61.1)</td>
<td>90.87</td>
</tr>
<tr>
<td></td>
<td>Complex (RT in ms)</td>
<td>574.62 (78.7)</td>
<td>587.57 (90.2)</td>
<td>12.94 (46.0)</td>
<td>87.30</td>
</tr>
<tr>
<td></td>
<td>Simple (z scores)</td>
<td>-0.503 (0.70)</td>
<td>0.192 (0.92)</td>
<td>0.694 (0.64)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Complex (z scores)</td>
<td>0.581 (0.82)</td>
<td>0.716 (0.94)</td>
<td>0.135 (0.48)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Bilingual Simple (RT in ms)</td>
<td>499.94 (150.5)</td>
<td>530.68 (132.8)</td>
<td>30.74 (41.9)</td>
<td>93.43</td>
</tr>
<tr>
<td></td>
<td>Complex (RT in ms)</td>
<td>595.98 (134.8)</td>
<td>615.78 (174.5)</td>
<td>19.80 (76.0)</td>
<td>90.05</td>
</tr>
<tr>
<td></td>
<td>Simple (z scores)</td>
<td>-0.196 (1.57)</td>
<td>0.122 (1.39)</td>
<td>0.318 (0.44)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Complex (z scores)</td>
<td>0.803 (1.40)</td>
<td>1.009 (1.82)</td>
<td>0.206 (0.79)</td>
<td></td>
</tr>
</tbody>
</table>
(SD = 0.62) and 0.09 (SD = 0.42) for the monolinguals. A significant interaction was found among language group, age group, and complexity on the Simon task across conditions, \( F(1,229) = 4.74 \) \( p = 0.03 \), \( \eta^2 = 0.02 \). The same findings were obtained with RTs (language effect, simple condition, \( F(1,229) = 7.14 \), \( p < 0.001 \), \( \eta^2 = 0.059 \); language effect, complex condition, \( F(1,229) = 0.92 \) \( p = 0.40 \), \( \eta^2 = 0.08 \); language \( \times \) age \( \times \) complexity \( F(1,229) = 4.64 \) \( p = 0.03 \), \( \eta^2 = 0.02 \).

### Accuracy rates

The analysis demonstrated that under the simple condition of the Simon task, accuracy rates were similar for both language groups, \( F(1,231) = 2.03 \), \( p = 0.15 \), \( \eta^2 = 0.009 \). Monolinguals had an accuracy rate of 92.72 per cent (SD = 8.09). Bilinguals had an accuracy rate of 94.16 per cent (SD = 6.22). The same was found under the complex condition, \( F(1,231) = 0.90 \), \( p = 0.444 \), \( \eta^2 = 0.004 \). Monolingual participants had an accuracy rate of 90.08 per cent (SD = 10.72) while bilingual participants had an accuracy rate of 91.35 per cent (SD = 9.26).

### 3.2 Balanced and non-balanced bilinguals

Analyses comparing the Simon effect between monolinguals, balanced bilinguals, and non-balanced bilinguals from the two age groups in the simple condition revealed that in the older group, monolinguals differed significantly from the balanced bilingual group, \( F(1,72) = 6.73 \), \( p = 0.01 \), \( \eta^2 = 0.08 \) and from the non-balanced group, \( F(1,68) = 9.24 \), \( p = 0.03 \), \( \eta^2 = 0.12 \); however, no significant differences were found between the two language groups, \( F(1,57) = 0.29 \), \( p = 0.58 \), \( \eta^2 = 0.005 \). In the younger group no significant differences were seen among any of the language groups (Figure 1).

### 4. Discussion

The present study attempted to analyze further the potential bilingual advantage in an inhibitory control task but with a larger sample of bilinguals who had not necessarily attained equal levels of proficiency in both of their languages. This type of bilingual is probably more representative of the bilinguals found world-wide, many of whom did not acquire their second language until adulthood or do not use both of their languages equally on a daily basis. In addition, the present study uses as the dependent measure transformation \( z \) scores of the RT providing a control for the slowness that takes place with aging.

As expected, older bilinguals were more efficient at inhibiting irrelevant information than older monolinguals but only under the simple Simon condition. The bilingual advantage was not seen in the younger sample. In other words, while older bilinguals demonstrated smaller Simon effects than the older monolinguals on the simpler Simon task, their younger counterparts did not show such a difference. This finding supports an attenuation of the age-related declines observed in inhibitory control processes in bilingual participants (Bialystok, Martin, & Viswanathan, 2005).

However, the present findings only partially replicated Bialystok et al. (2004), who found language group differences under both the simpler and more complex conditions of the Simon task. In our study, the complex condition showed no difference in the Simon effect between the two language groups. The discrepancies in results between the two studies may be due to differences in the sample size and sample characteristic in each of the two studies. First, the mean age of the participants was dissimilar in the two studies. The younger bilinguals (\( N = 32 \)) in the Bialystok et al. study (study 2) had a mean age of 42.6 years (range 30 to 58 years), while the older bilinguals (\( N = 15 \)) had a mean age of 70.3 years (range 60 to 80). Both groups of bilinguals were younger in the present study. The mean age of the younger bilinguals (\( N = 67 \)) was 26.67 years. For the older
bilinguals ($N = 58$), the mean age was 64.12 years. It may be that the positive effect of bilingualism on the attenuation of the declines in complex inhibitory control becomes apparent only in much older adults with more years of bilingual experience.

Another source of difference between the two samples was the type of bilingualism. All bilinguals in the present study were Spanish–English bilinguals. The majority of the bilingual participants in the Bialystok et al. study consisted of Tamil–English and Cantonese–English which according to Ardila (2007) would be considered stronger bilingualism (rather different linguistic systems) than Spanish–English bilingualism, which are closer in terms of the functional distance (differences between two language in pronunciation, grammar, vocabulary, orthography, and writing) between both languages. It seems reasonable to suggest that long-time experience with ‘strong’ bilingualism may result in a higher bilingual advantage in terms of inhibitory control. In fact, differences in brain activation during an inhibitory control task have been reported for Cantonese–English speakers compared to French–English speakers (Bialystok, Craik et al., 2005) showing faster responses and greater brain activation for the Cantonese–English speakers. Further research should test this hypothesis.

Other important differences in comparing the samples of the two studies reside in the level of education of the participants and the number of years of bilingual experience. All participants in Bialystok et al.’s study had bachelor’s degrees while the participants of the current study had lower education levels.
levels of formal education. Previous studies have suggested that the number of years of education is a factor in the cognitive beneficial effects of mental activities (Arbuckle, Maag, Pushkar, & Chaikelson, 1998). In addition, all of Bialystok et al.’s participants had been educated in both languages since the age of six, and all used both of their languages on a daily basis. This suggests that the bilingual sample most likely consisted of high-proficient, early balanced bilinguals. Meanwhile, the younger participants in the present study acquired L2 at a mean age of 10.95 years, while the older ones acquired L2 at a mean age of 22.21 years. All of this seems to indicate that many of our participants were late bilinguals. So, it may be that although late bilingualism is enough to demonstrate an advantage in some tasks of inhibitory control, the longer the bilingual experience the greater the advantage of bilingualism in tasks of working memory demands at an older age.

Earlier research has indicated that cognitive advantages conferred by bilingualism are often observed only in balanced bilinguals (Bialystok, Craik, & Ruocco, 2006; Bialystok, & Majumder, 1998; Cummins, 1977; Ricciardelli, 1992). In the current study there was no difference in the Simon effect between balanced and non-balanced bilinguals, suggesting that partial bilingualism may confer positive effects. Even limited experience with a second language may be enough to influence the ability to reduce attention to distracting linguistic information. This unpredicted finding is in line with previous reports of greater cognitive control advantages to non-balanced bilingual children compared to monolingual children (Bialystok, 1988); but it contradicts findings by other authors. For example, Bialystok, Craik and Ruocco (2006) found a bilingual advantage in balanced but not in non-balanced bilinguals in a visual classification task while both language groups maintained high performance in an auditory task. Contradictory findings may be due to differences between the two studies in the characteristics of the balanced bilingual sample and in the nature of the tasks. The non-balanced bilinguals in Bialystok et al’s study were different from their balanced bilinguals not just in language proficiency but in terms of the frequency of use of the two languages: while the balanced bilinguals use both languages on a daily bases the non-balanced bilinguals reported use of the second language weekly or monthly. On the contrary, in our study the bilingual sample lived in a Spanish–English environment (South Florida) and used both languages on a daily basis; only language proficiency and not frequency of use of the two languages distinguished the balanced from the non-balanced groups. Therefore the non-balanced bilinguals of the current study were clearly more active bilinguals than the non-balanced bilinguals included in Bialystok’s study. Also, while the Simon task used in the current study relies minimally on linguistic process, the dual decision task used in Bialystok et al.’s research required verbal responses, and language proficiency may have played a significant role in the lack of advantage of the non-balanced group. It is important that future research address the performance in verbal and non-verbal decision tasks of bilinguals, distinguishing levels of language proficiency and degrees of activation of the two languages.

Another unexpected finding about the bilingual advantage in the simple condition was that older bilinguals were actually slower than monolinguals in the congruent condition; however, the difference between congruent and incongruent trials was larger for monolinguals than for bilinguals. Costa, Hernández, and Sebastián-Gallés (2008) showed that the bilingual advantage can be modified by the characteristics of the tasks. They demonstrated for example that the speed of response in bilinguals compared to monolinguals could be affected significantly when the task requires switching from incongruent to congruent trials in a conflict resolution task. This bilingual effect was not seen when the switching was in the other direction (from congruent to incongruent). Moreover, the authors observed that the bilingual advantage is more likely to be observed when the task is over practiced. Although we did not analyze the effects of the type of trial, it may be possible that the difference between bilinguals and monolinguals of our study in the congruent trials
was associated with practice effects. In fact, we used 72 congruent and 72 incongruent trials, fewer than those used by Costa et al. Future studies need to address the effects of practice on the bilingual advantage in inhibitory tasks of the Simon type.

It is interesting to note that there is large variation in the size of the Simon effect in the simple condition across studies. For example, the Simon effect reported for young samples has ranged from 20 and 35 ms (van der Lubbe & Verleger, 2002; and Experiment 2 in Castel, Balota, Hutchison, Logan, & Yap, 2007 respectively) to 123 ms (monolinguals in Bialystok et al., 2004) and for older groups from 48 and 96 ms (van der Lubbe & Verleger, 2002 & Experiment 2 in Castel et al., 2007 respectively) to 583 ms (monolinguals in Bialystok et al., 2004). The Simon effects obtained in the current study (simple condition) are closer to those reported by Castel et al. (2007) and Protor, Pick, Vu, & Anderson (2005); indeed, the RTs obtained in this study were almost identical to those reported by Protor et al. but shorter than those described elsewhere (e.g. Bialystok et al., 2004; Castel et al., 2007). One possible explanation for shorter RTs is that the current study excluded participants using the WAIS Block design criterion. Since this subtest involves timing, inadvertently we may have selected a faster RT sample.

The findings from the current study showed a clear difference in the size of the Simon effect between the simple and the complex conditions in all groups. A larger Simon effect was found for faster RTs (simple condition), in concordance with previous analyses of the Simon effect and speed of response (Buetti & Kerzel, 2009; Hommel, 1995). Buetti and Kerzel (2009) found that the Simon effect was larger for the fastest RTs and decreased as RTs increased. As an explanation for this pattern, the authors suggested insufficient response preparation and high response conflict in slow responses.

In our study, bilingualism had an effect on the task that requires faster RTs, the simple condition that is strictly assessing inhibitory control abilities. Additionally, besides assessing inhibitory control efficiency, the complex condition also assesses working memory ability. Adding a second demand by increasing working memory load appears to have a greater impact on the congruent trials compared to incongruent trials, leading to smaller Simon effects under this condition and to no bilingual advantage. Our results are consistent with recent findings by Hernández, Costa, Fuentes, Vivas, and Sebastián-Gallés (2010), who found an evident bilingual advantage in a simple task of inhibitory control of the Stroop type, whereas no significant difference was observed in the performance of bilinguals compared to monolinguals in a more complex task of orientation of attention.

The results from the present study may contribute to the understanding of the influence of bilingualism on inhibitory control tasks in bilinguals whose level of proficiency in each of their two languages varied widely. Results support the notion that the acquisition of two languages increases skills that are associated with selective attention, but they do not support the extension of this advantage to inhibitory tasks that involve high working memory demands. Also, results showed that the bilingual advantage is age dependent. The advantage was found in the elderly but was absent in young adults. Furthermore, our findings reported that the bilingual advantage extended to individuals with non-balanced bilingualism but with daily exposure to the bilingual experience. This finding suggests that the positive effects of bilingualism may depend on the level of linguistic activation rather than on language proficiency. Further research needs to analyze the association of language proficiency and language switching to the magnitude of the bilingual advantage. Also, future research is required to identify the effect of age of acquisition of the second language and on the magnitude of this advantage. Although the results from this study partially support the association between mentally stimulating activity and level of cognitive performance, more data are needed before it can be concluded that bilingualism is a protective factor against age-cognitive decline (Salthouse, 2005).
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Note

1 This study has several limitations. First, the sample size is small and the age range is limited. Future research with a larger sample of balanced and non-balanced bilinguals and with a larger age range is needed to provide higher statistical power. In addition, this study was cross-sectional, and to test the prediction that bilingualism protects against age-related cognitive changes a longitudinal design may be more valid.

References


