Running head: Language control in bilinguals and interpreters

Verbal and non-verbal cognitive control in bilinguals and interpreters*

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Abstract

The present study explored the relation between language control and non-verbal cognitive control in different bilingual populations. We compared monolinguals, Dutch-French unbalanced bilinguals, balanced bilinguals, and interpreters on the Simon task and Attention Network Test (ANT). All bilingual groups showed a smaller congruency effect in the Simon task than the monolingual group. They were also faster overall in the ANT. Furthermore, interpreters outperformed unbalanced, but not balanced, bilinguals in terms of overall accuracy on both tasks. In the ANT, the error congruency effect was significantly smaller for interpreters and balanced bilinguals. Using a measure of switching fluency in language production, this study also found direct evidence for a relation between language control and executive control. This relation was only observed in balanced bilinguals, where fluent switching was correlated with the Simon effect. These findings support the existence of a bilingual advantage and also indicate that different patterns of bilingual language use modulate the nature and extent of a cognitive control advantage in multilingual populations.

Keywords: bilingualism, interpreting, language control, language switching, cognitive control

Introduction

Recently, the literature on bilingualism has taken great interest in the impact of bilingualism on executive control outside the linguistic domain. Bilinguals have two languages that are activated simultaneously (Kroll, Bobb, & Wodniecka, 2006; Van Assche, Duyck, & Hartsuiker, 2012) and therefore require mechanisms to suppress the inappropriate language and activate the appropriate one. The constant competition for selection that takes place between languages may lead to enhanced cognitive control that is not language-specific, but domain-general (Green, 1998). Several studies have investigated the performance of bilinguals on different tasks that require executive processing and found that bilinguals often outperform monolinguals, responding faster overall and showing more rapid conflict resolution. These results have been observed throughout all stages of the bilingual lifespan (Bialystok, Martin, & Viswanathan, 2005); from childhood (Bialystok, 2005) over young adulthood (Bialystok, 2006; Costa, Hernández, & Sebastian-Gallés, 2008) to middle and old age (Bialystok, Craik, & Luk, 2008; Bialystok, Klein, Craik, & Viswanathan, 2004).

Challenges

Although many studies yield compelling evidence for a bilingual advantage, there are others that do not (see Hilchey & Klein, 2011). For instance, Morton and Harper (2007) did not find any difference between monolingual and bilingual children on Simon task performance, but they did record an effect of socioeconomic status (SES). Both Duñabeitia et al. (2014) and Antón et al. (2014) compared large groups of well-matched monolingual and bilingual children on different measures of cognitive control and found no differences either. Kousaie and Phillips (2012) found the same for younger and older adults. In contrast, other studies controlling for SES, intelligence, and other variables did find evidence for a bilingual advantage (e.g. Engel de Abreu, Cruz-Santos, Tourinho, Martin, & Bialystok, 2012; Nicolay & Poncelet, 2013).

The reason for the discrepancies between studies is not yet clear. Paap and Greenberg (2013) suggested that different tasks used in bilingual studies might elicit different results. They employed 15 indicators of cognitive processing, but none yielded bilingual effects. It must be noted that their participants were classified as monolingual even when they had L2 knowledge, providing that L2 proficiency did not exceed the intermediate level. This rather subtle difference between bi- and monolinguals may have obscured the results. Bilingualism is a broad concept (Kroll & Bialystok, 2013) and language use parameters may influence the bilingual advantage. It may be sensitive to certain bilingual variables, such as L2 proficiency (Bialystok & Barac, 2012) and language switching experience (Green & Wei, 2014). With regard to the latter, Green and Abutalebi (2013) have stated in their 'adaptive control hypothesis' that the interactional context (e.g. contexts where frequent language switching is necessary) lead bilinguals to adapt their cognitive control processes and tune their control networks.

Some experimental studies provided evidence for this hypothesis by reporting an explicit link between language control and cognitive control. For instance, Prior and Gollan (2013) observed that task training led to a reduction in language-switching cost. They also demonstrated that Spanish-English bilinguals who reported frequent language switching in daily life exhibited smaller task-switching costs than monolinguals, while a group of Mandarin-English bilinguals who reported less frequent language switching did not show this advantage (Prior & Gollan, 2011). However, as this latter study confounded switching frequency with cross-language overlap (Spanish-English vs. Mandarin-English), Verreyt, Woumans, Szmalec, Vandelanotte, and Duyck (in press) recently generalised these results within a single-language pair. Only balanced Dutch-French bilinguals that switched languages often during the course of a day showed a bilingual advantage relative to unbalanced bilinguals. Together these findings reveal that different linguistic variables can modulate the magnitude of the bilingual advantage and even provide an explanation for the discrepancies in the results of different studies.

Experts in language control: the case of interpreters

Bilingual studies tapping into cognitive control have employed all sorts of bilingual populations. Surprisingly, a population that has not been extensively investigated is one in which extreme between-language control takes place; simultaneous interpreters. Simultaneous interpreting is the complex task of reformulating spoken messages from the source language (SL) into the target language (TL), while monitoring all produced output. This means that both language systems need to be simultaneously activated for comprehension and production (de Groot & Christoffels, 2006). Nevertheless, some sort of inhibition must take place in order for interpreters to produce the correct language. Christoffels and de Groot (2005) describe possible inhibition accounts of interpreting, assuming (functionally) distinct input and output lexicons that can be separately activated and inhibited. These accounts state that both SL and TL input lexicons should be activated, to allow for input comprehension and output monitoring, while the SL output lexicon should be strongly inhibited. Interpreting involves many cognitive processes (e.g. attention, memory, inhibition) at the same time and these may be trained due to the frequent usage.

Indeed, several studies have found evidence for enhanced working memory in this population. For instance, Köpke and Nespoulous (2006) compared expert interpreters, novice interpreter students, and two control groups (monolinguals and bilinguals) and ascertained superior performance of novice interpreters on memory span. The distinctive performance between novice and expert interpreters was explained in light of differences in age, screening processes, and memory training. In another study, Christoffels, de Groot, and Kroll (2006) compared trained interpreters to highly proficient English teachers and 20-year younger bilingual university students, and found that interpreters again performed notably better on memory. Additionally, they included a basic non-verbal cognitive control task, but found no advantage for interpreters here. Yudes, Macizo, and Bajo (2011) further explored executive processes in interpreters, by comparing them to monolinguals and bilinguals on the Simon task and the Wisconsin Card Sorting Test (WCST). This study also disclosed a relation between interpreting and cognitive flexibility, as the interpreters outperformed bilinguals and monolinguals on the WCST. This was not the case for inhibitory control, as they did not do better on the Simon task.

Evidently, interpreters seem to be advantaged on measures of memory, but there have thus far been no strong indications that they also possess better inhibitory control. It must, however, be noted that both Christoffels et al. (2011) and Yudes et al. (2011) had similar age confound problems, as the interpreters were much older that the other participants. Nevertheless, when Yudes et al. performed the same analyses on a smaller group of interpreters and bilinguals matched on age, the same pattern of results was obtained. Even so, it is possible that better controlled studies may still yield control advantages for interpreters.

The present study

It recently became clear that bilingual control advantages are not consistently observed. This taken together with the fact that some studies reported effects of particular bilingual experiences led us to believe that it might be these experiences that modulate the bilingual advantage and determine its existence. Hence, we investigated the effect of bilingual proficiency and interpreter training; comparing monolinguals, unbalanced bilinguals, balanced bilinguals, and student interpreters matched for age, gender, and intelligence on cognitive control tasks. In addition, we directly relate a measure of language switching with domain-general conflict resolution.

Language-switching proficiency was measured through an adapted dual-language version of the semantic verbal fluency task, similar to Yim and Bialystok (2012). In semantic fluency, participants retrieve as many words possible within a given category. Hence, performance is semantically and internally driven, like natural word production. Yim and Bialystok found a correlation between conversational language switching and switching costs in the fluency task, indicating that it is an accurate measure of natural switching proficiency. Our task consisted of two single-language conditions (French and Dutch) and a dual-language condition, in which participants were instructed to alternate constantly between languages. As switching languages is costly (Gollan & Ferreira, 2009), we expected our participants to generate fewer exemplars in the dual-language condition (switch cost). The two single-language conditions also served as an online indicator of L1 and L2 proficiency, adding to the results of the self-reported measures.

Miyake and Friedman (2012) noted that different types of control tasks often elicit diverse results, as they tap into other kinds of inhibitory control. Therefore, we employed both the Simon task (Simon & Rudell, 1967) and the ANT (Fan, McCandliss, Sommer, Raz, & Posner, 2002). The Simon task is based on stimulus-response compatibility, meaning that the difficulty lies in inhibiting a prepotent response. Coloured dots appear either on the left or right side of the screen, but participants are asked to ignore position and respond to colour by pressing either a left or right button. Inhibition is required when position and colour elicit different responses. In the ANT, participants must indicate the direction of the central of five arrows. Conflict takes place on screen when the central arrow points into the other direction as the other arrows and interference inhibition is needed.

We suspect that particular bilingual experiences modulate the bilingual control advantage and hypothesise that more language control practice leads to enhanced cognitive functioning. Firstly, we predict that bilinguals are better equipped to deal with conflict resolution than monolinguals. Secondly, we expect balanced bilinguals and interpreters to outperform unbalanced bilinguals, due to their extensive experience with language inhibition, and assume that interpreting practice leads to even greater advantages. Interpreters constantly handle both languages at the same time, but have a need to suppress the input language when they are busy producing the output language. Thirdly, within bilingual groups, we postulate that cognitive control is better in bilinguals with superior language-switching abilities. Frequently alternating between languages in daily life should improve language switching in the fluency task and yield an associated cognitive advantage, at least for balanced bilinguals and interpreters. Such association is less likely for unbalanced bilinguals, as they have virtually no or only limited experience in switching languages.

Method

Participants

We included a group of 30 French-speaking monolinguals and three groups of Dutch-French bilinguals; 34 unbalanced bilinguals, 31 balanced bilinguals, and 28 student Dutch-French interpreters. All participants were recruited at universities and colleges in Ghent, Brussels, and Louvain (Belgium). A language questionnaire and verbal fluency task were administered as a measure of proficiency. Balanced bilinguals were equally proficient in L1 and L2 and employed both languages to the same extent in daily life. Unbalanced bilinguals acquired their L2 through formal education and rarely used it outside school context, while monolinguals indicated they had no or very little knowledge of any other language. The inclusion criterion for the interpreter group was the completion (or near-completion) of a one-year Master programme in Dutch-French interpreting with 10 hours of interpreting per week. All balanced bilinguals were early L2 learners and reported lower L1 proficiency than monolinguals, unbalanced bilinguals, and interpreters. Interpreters indicated they were more proficient in L2 than unbalanced bilinguals, but less proficient than balanced bilinguals. There was no difference in age of L2 acquisition between interpreters and unbalanced bilinguals; both groups consisted mostly of late L2 learners. All groups were matched for age, gender, and intelligence. Detailed demographic information is reported in Table 1.

Table 1. *Demographic data of the different bilingual populations.*

	Monolingual	Unbalanced	Balanced	Interpreter	Test	*p*
N	30	34	31	28		
Male/female ratio	8/22	7/27	7/24	6/22	$Chi^2(3) = .380$	> .05
Age	22.1 (1.4)	22.3 (2.8)	21.1 (2.1)	22.5 (1.7)	$F_{3,119} = 1.78$	> .05
Raven	9.0 (2.5)	8.3 (2.7)	8.6 (2.1)	9.6 (1.6)	$F_{3,119} = 1.80$	> .05
L1 French/Dutch	30/0	0/34	13/18	2/26		
L1 Proficiency	5.0 (0.0)	5.0 (0.0)	4.8 (0.3)	5.0 (0.2)	$F_{3,119} = 4.95$	< .01
Age of acquisition	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	No differences	
Frequency of use (%)	98.0 (2.0)	92.3 (7.1)	64.6 (13.5)	70.2 (20.3)	$F_{3,119} = 40.97$	< .001
L2 Proficiency	1.8 (1.0)	2.6 (0.6)	4.2 (0.5)	3.7 (0.5)	$F_{3,119} = 72.76$	< .001
Age of acquisition	12.4 (2.4)	9.4 (1.3)	2.6 (3.0)	8.6 (3.3)	$F_{3,119} = 74.47$	< .001
Frequency of use (%)	2.0 (2.0)	7.7 (7.1)	35.5 (13.5)	25.6 (14.7)	$F_{3,119} = 53.33$	< .001
Fluency L1	20.2 (7.3)	17.7 (6.1)	16.7 (5.6)	18.2 (4.4)	$F_{3,119} = 1.88$	> .05
Fluency L2	N/A	5.9 (3.0)	12.8 (5.4)	14.0 (4.0)	$F_{2,90} = 34.48$	< .001
Fluency switching	N/A	8.2 (2.8)	11.4 (3.2)	11.9 (3.3)	$F_{2,90} = 13.69$	< .001
Switching cost	N/A	3.7 (4.6)	3.3 (3.9)	4.2 (4.4)	$F_{2,90} = 0.31$	> .05

Materials and procedure

Task instructions were given in French for monolinguals and in either Dutch or French for bilinguals, depending on which the participants preferred.

Language background. Participants completed a questionnaire about use and fluency in one or more languages. A 5-point Likert scale tapped into four language skills (comprehending, speaking, reading, and writing), ranging from 1 (very poor) to 5 (native speaker level). A composite proficiency score was calculated by averaging responses for all skills. All bilingual groups also reported knowledge of a third language, but this knowledge was similar in the three groups.

Raven's Advanced Progressive Matrices. Raven's Matrices is a test of analytic reasoning and is considered to be a good non-verbal index of general fluid intelligence. The Advanced Progressive Matrices (Raven, 1965) is a 48 item-version of the matrices intended for use with people of above average aptitude. We administered the short untimed 12 item-version, which correlates highly with the complete version (Bors & Stokes, 1998), in order to ascertain whether our groups obtained similar intelligence scores.

Semantic Verbal Fluency. Verbal fluency was administered as a measure of verbal language control. We used two single-language conditions (Dutch and French) and one dual-language (switch) condition. Participants were given 60 seconds to verbally produce as many exemplars as they could of a given semantic category. The categories used in this study were *animals*, *vegetables*, and *professions*. Monolinguals performed all three categories in French[1]. For bilinguals, categories were counterbalanced across language conditions. Participants could either be instructed to start with the French or Dutch condition; however, the dual-language condition was always performed last, in order to avoid continuing language switches in the single-language blocks. During this last condition, participants were required to constantly alternate between the two languages. Consecutively giving two exemplars in the same language was considered an error and translations of previously produced were also not allowed. Per participant, the results of the single-language L1 condition were then compared with the amount of L1 exemplars in the dual-language condition. The difference between the two was used as a cost for language switching (small difference = fluent switching, large different = non-fluent switching).

[1] The amount of exemplars given per semantic category was compared across monolinguals. No significant differences were found (*p* = .397).

Simon task. A coloured Simon task was used to assess non-verbal executive functions. Coloured dots appeared either on the left or right side of the screen and participants were asked to press the left (right) key on the keyboard when a green dot appeared, and the right (left) key when the red dot appeared as quickly and as accurately as possible. Response mapping was counterbalanced across participants. Position and colour elicited either the same response (congruent trials) or different responses (incongruent trials).

Each trial began with a fixation cross that remained visible for 500 ms, followed by a clear screen, after which a red or green dot appeared either on the left or right side of the screen. The presentation of the coloured dot lasted until the participant's response or up to 900 ms. There was a 500 ms blank interval before the next fixation period. The experiment consisted of 10 randomised practice trials and two blocks of 100 randomised experimental trials. Half of all trials presented the coloured dot on the same side of the associated response key, and half on the opposite side. Stimuli were presented via Tscope software (Stevens, Lammertyn, Verbruggen, & Vandierendonck, 2006) on an IBM-compatible laptop computer with a 15-inch screen, running XP.

ANT. A shortened ANT-version was employed, measuring the executive and orienting network. Participants were shown five arrows and asked to indicate the direction of the central one. The experimental design contained two within-subject factors: flanker type (congruent and incongruent) and cue type. Cues assessed orienting skills and were presented at the location of fixation (centre cue) or at the location of the upcoming target (spatial cue). Sometimes, no cue was presented.

Comparing congruent and incongruent trials measured the executive network, comparing central and spatial cue trials quantified the orienting network.

A session consisted of a 6-trial demo block, a 12-trial full feedback practice block, and three experimental blocks of 48 randomised trials. Each condition was shown an equal amount of times (once during the demo, twice during practice, eight times per experimental block). Each trial consisted of five events: (1) a fixation of a random variable duration (400-1600 ms), (2) a cue for 100 ms, (3) another fixation of 400 ms, (4) target arrow and flankers above or below fixation until response or up to 1700 ms, (5) clearing the screen after response. In the no cue condition, there was no step two or three. Participants were instructed to focus on the fixation cross and respond as quickly and accurately as possible. They pressed the left button of a touchpad with their left hand when the target pointed to the left, and the right button of that touchpad with their right hand when the target pointed to the right. Stimuli were presented via E-Prime on an IBM-compatible laptop computer with a 15-inch screen, running XP.

Results

Verbal fluency. All data are reported in Table 1. The amount of exemplars produced in the L1 condition did not differ between groups. In the L2 condition, unbalanced bilinguals produced significantly fewer exemplars than balanced bilinguals ($t_{63} = 6.27$, $p < .001$) and interpreters ($t_{60} = 8.89$, $p < .001$). Balanced bilinguals and interpreters performed similarly ($t_{57} = -1.02$, $p = .312$). Results for the dual-language condition were analogous, with unbalanced bilinguals producing significantly fewer words than balanced bilinguals ($t_{63} = 4.29$, $p < .001$) and interpreters (t_{60} = 4.72, p < .001), while balanced bilinguals and interpreters did not differ (t_{57} = -0.60, p = .548).

Conflict tasks. For each participant, mean response latencies (RT) and mean error percentages were calculated. Table 2 shows all results for Simon and ANT. Two participants (one balanced and one unbalanced bilingual) were excluded from analysis, because they had an error rate of more than 50% for the Simon task (chance level), while the mean error rate was 2.0%. For the ANT, the error rate was on average 3.6%. RTs for incorrect responses were excluded from analyses. Outlier RTs were trimmed individually by calculating a mean RT across all trials and excluding any response 2.5 SD of the mean. This procedure eliminated 2.4% of all Simon data and 2.2% of all ANT data. The reliability of RTs as estimated using the intraclass correlation (ICC(C,k), to be specific) was 98.4% (95% CI = [91.66, 99.99]). Note that ICC(C,k) corresponds to the split-half reliability averaged over all possible data splits (Shrout & Fleiss, 1979). For both tasks, Congruency was manipulated within subjects, while Group was a between-subject variable. For the ANT, Cue effect was also analysed. Furthermore, significant correlations between conflict tasks and language-switching cost are reported.

Table 2. *Mean RTs (ms) and error rates (%) for Simon and ANT by Group and broken for congruency, with standard deviations in parentheses.*

	Simon				*ANT*			
	Monolingual	Unbalanced	Balanced	Interpreter	Monolingual	Unbalanced	Balanced	Interpreter
RT								
Congruent	383 (64)	393 (54)	415 (47)	409 (41)	521 (62)	474 (53)	497 (45)	496 (39)
Incongruent	422 (65)	422 (55)	442 (49)	437 (38)	614 (73)	562 (70)	577 (48)	587 (64)
Congruency effect	38 (18)	29 (12)	27 (15)	28 (21)	93 (45)	88 (26)	81 (16)	91 (34)
Orienting effect	N/A	N/A	N/A	N/A	38 (30)	48 (19)	59 (23)	65 (23)
Error rates								
Congruent	2.6 (2.5)	4.9 (4.7)	4.6 (3.9)	2.6 (2.3)	0.5 (0.9)	0.6 (0.9)	0.8 (1.2)	0.3 (0.8)
Incongruent	7.1 (4.5)	7.8 (5.5)	6.4 (5.4)	5.8 (4.2)	6.1 (5.3)	9.2 (8.2)	5.7 (6.0)	4.4 (3.8)
Congruency effect	4.4 (4.6)	3.0 (5.4)	1.7 (5.1)	3.1 (3.5)	5.6 (5.0)	8.6 (7.9)	4.9 (5.7)	4.1 (3.8)
Orienting effect	N/A	N/A	N/A	N/A	1.7 (3.3)	3.4 (6.4)	2.4 (4.3)	1.3 (2.2)

Monolinguals vs. bilinguals

If a bilingual cognitive control advantage exists, it would translate into faster RTs and higher accuracy overall and a smaller congruency effect in both conflict tasks for all bilingual groups as opposed to the monolingual group.

Simon task. In the RT analysis, the effect of Congruency was significant ($F_{1,119}$ = 416.54, $p < .001$, $\eta p^2 = .778$), with faster RTs for congruent trials. There was no main effect of Group ($F_{3,119} = 1.70$, $p = .171$, $\eta p^2 = .041$). Planned comparisons showed no differences between groups. There was, however, a significant Congruency*Group interaction ($F_{3,119} = 3.01$, $p = .033$, $\eta p^2 = .070$). Planned comparisons revealed a larger Simon effect for monolinguals compared with all other groups ($t_{119} = 2.98$, $p = .004$). Error analysis yielded an effect of Congruency ($F_{1,119}$ = 50.80, $p < .001$, $\eta p^2 = .299$), with more errors on incongruent trials. No effect of Group was found ($F_{3,119} = 1.97$, $p = .123$, $\eta p^2 = .047$). Neither was there an interaction ($F_{3,119} = 1.67$, $p = .176$, $\eta p^2 = .040$) and planned comparisons did not reveal any significant differences.

ANT. RT analysis yielded a main effect of Congruency ($F_{1,119} = 937.14$, $p <$ .001, $\eta p^2 = .887$), with smaller RTs for congruent trials, and of Group ($F_{3,119} = 4.34$, $p = .006$, $\eta p^2 = .099$). Planned comparisons showed that monolinguals had higher overall RTs than the other groups ($t_{119} = 2.89$, $p = .005$). No Congruency*Group interaction was found ($F_{3,119} = 0.84$, $p = .475$, $\eta p^2 = .022$) and planned comparisons revealed no differences between monolinguals and the other groups. The orienting analysis revealed an effect of Cue ($F_{1,119} = 593.63$, $p < .001$, $\eta p^2 = .833$), indicating faster responses on spatial cue trials. Planned comparisons indicated that bilinguals benefited more from the presence of a spatial cue than monolinguals (t_{119} = -3.96, p < .001). Error analysis produced an effect of Congruency ($F_{1,119}$ = 118.19, p < .001, ηp^2 = .498), with fewer errors in the congruent condition. There was also an effect of Group ($F_{3,119}$ = 3.18, p = .027, ηp^2 = .074) and a Group*Congruency interaction ($F_{3,119}$ = 3.55, p = .017, ηp^2 = .082). Planned comparisons did not show differences between monolinguals and the other groups. The orienting analysis for errors revealed an effect of Cue ($F_{1,119}$ = 30.38, p < .001, ηp^2 = .203), but no other effects.

Both tasks demonstrated a cognitive control advantage for bilinguals relative to monolinguals. It was reflected by a smaller RT congruency effect in the Simon task and faster overall RTs in the ANT for bilinguals.

Bilinguals vs. interpreters

If interpreting experience modulates the bilingual advantage, we would expect better performance for interpreters on both the Simon task and the ANT as compared with the other two bilingual groups.

Simon task. In the RT analysis, the effect of Congruency was significant ($F_{1,90}$ = 279.87, p < .001, ηp^2 = .757). However, no effect of Group ($F_{2,90}$ = 1.68, p = .192, ηp^2 = .036) or Congruency*Group interaction ($F_{2,90}$ = .080, p = .923, ηp^2 = .002) was found. Error analysis yielded an effect of Congruency ($F_{1,90}$ = 27.18, p < .001, ηp^2 = .232), but not of Group ($F_{2,90}$ = 2.37, p = .099, ηp^2 = .050). Planned comparisons showed interpreters made significantly fewer errors than unbalanced bilinguals (t_{60} = -2.31, p = .025), but did not do better than balanced bilinguals (t_{57} = 1.43, p = .158). There was no significant difference between balanced and unbalanced bilinguals (t_{63} = -0.81, p = .421). Neither was there a Group*Congruency interaction ($F_{2,90}$ = 0.81, p = .448, ηp^2 = .018).

ANT. RT analysis yielded an effect of Congruency ($F_{1,90}$ = 997.88, p < .001, ηp^2 = .917), but no effect of Group ($F_{2,90}$ = 1.83, p = .167, ηp^2 = .039) or a Group*Congruency interaction ($F_{2,90}$ = 1.24, p = .294, ηp^2 = .027). The orienting analysis revealed an effect of Cue ($F_{1,90}$ = 657.32, p < .001, ηp^2 = .880). Planned comparisons showed that unbalanced bilinguals benefited less from the presence of a spatial cue than balanced bilinguals (t_{63} = -2.07, p = .042) and interpreters (t_{60} = -3.11, p = .003). Error analysis produced a significant effect of Congruency ($F_{1,90}$ = 83.61, p < .001, ηp^2 = .482) and of Group ($F_{2,90}$ = 4.39, p = .015, ηp^2 = .089). The total amount of errors was only marginally higher for unbalanced bilinguals compared with balanced bilinguals (t_{63} = -1.70, p = .093), and significantly higher compared with interpreters (t_{60} = -3.03, p = .004). Interpreters and balanced bilinguals did not differ (t_{57} = 1.29, p = .205). The Congruency*Group interaction was significant ($F_{2,90}$ = 4.83, p = .010, ηp^2 = .097), with unbalanced bilinguals having a larger congruency effect than balanced bilinguals (t_{63} = -2.15, p = .036) and interpreters (t_{60} = -2.94, p = .005). Interpreters did not differ from balanced bilinguals (t_{57} = 0.70, p = .490). The orienting analysis revealed a main effect of Cue ($F_{1,90}$ = 23.10, p < .001, ηp^2 = .204), but no other effects.

Interpreters showed cognitive control advantages on both tasks on overall accuracy scores, but only relative to unbalanced and not to balanced bilinguals. For the ANT, interpreters also had a smaller error congruency effect than unbalanced bilinguals.

Language control vs. cognitive control

If language control affects the bilingual advantage, language-switching abilities should be correlated to cognitive control in groups where L2 proficiency is high (i.e. balanced bilinguals and interpreters).

Simon task. Correlation analysis revealed a link between cost of switching languages in the fluency task and the Simon RT effect, but only in balanced bilinguals. Fluent switchers had a smaller effect ($r = .530$, $p = .002$). There were no correlations with error scores.

ANT. Only a weak relation was found between switch cost and the ANT error effect in interpreters ($r = .347$, $p = .070$), with lower switch costs relating to smaller error effects.

The results indeed indicate a relation between language switching and cognitive control, but only for balanced bilinguals on the Simon task, as better language switchers demonstrated smaller RT congruency effects.

Discussion

Recently, research on the bilingual advantage began yielding diverging results, with some studies not finding any advantage at all (e.g. Duñabeitia et al., 2014; Paap & Greenberg, 2013). In addition, several studies provided evidence that it may not be bilingualism in itself, but specific bilingual experiences modifying the advantage (e.g. Bialystok & Barac, 2012; Prior & Gollan, 2011). For this reason, we set out to clarify how L2 variables such as L2 proficiency, language-switching abilities, and interpreter training may determine the magnitude of the bilingual advantage.

Accordingly, we compared monolinguals, unbalanced bilinguals, balanced bilinguals, and student interpreters on the Simon task and the ANT. L2 proficiency was scored through self-report scales and semantic verbal fluency. Language-switching abilities within bilingual groups were measured by comparing the single-language conditions to a dual-language condition in the fluency task. The difference in performance generated a cost value for switching. We hypothesised that enhanced bilingual language control leads to improved cognitive functioning. Specifically, we expected all bilinguals to outperform the monolinguals, but also assumed greater advantages for balanced bilinguals and the greatest advantages for interpreters. Furthermore, we predicted a correlation between language control, assessed by language-switching proficiency, and cognitive control within these different bilingual populations.

Our results revealed a smaller Simon effect and faster overall RTs in the ANT for bilinguals compared with monolinguals. They were also aided more by the presence of a spatial cue in the ANT, suggesting better orienting. The three bilingual groups did not differ on overall RTs or congruency effect, but interpreters and balanced bilinguals exhibited better orienting skills than unbalanced bilinguals. Furthermore, interpreters made significantly fewer errors than unbalanced bilinguals in both tasks and the ANT error effect was significantly smaller for both interpreters and balanced bilinguals. Within groups, we established that fluent switching was associated with a smaller Simon effect in balanced bilinguals.

The bilingual advantage

The present study is in line with studies reporting a bilingual advantage (Bialystok et al., 2004; Costa et al., 2008), as it determined a smaller Simon effect and faster overall RTs in the ANT for bilinguals compared with monolinguals. The ANT results converge with those of Costa, Hernández, Costa-Faidella, and Sebastián-Gallés (2009), who attributed the overall effect to a more efficient monitoring system in bilinguals.

Contrary to Costa et al. (2008, 2009), our results showed that bilingualism was also associated with better orienting. As we employed a shorter version of the same task, these discrepancies cannot be accounted for by the nature of the measures. Consequently, we propose that the difference lies in how attentive bilinguals are to cues. Costa's bilinguals all lived in Catalonia where almost everyone speaks both Spanish and Catalan. Since not everyone in Belgium is fluent in both Dutch and French, our bilinguals have a need to look for certain contextual cues to know which language they should use (cf. Poulisse & Bongaerts, 1994). It is feasible that this particular experience has made them more perceptive to all sort of orienting cues.

The fact that we did not consistently find better overall RTs and smaller congruency effects for bilinguals on both tasks supports Miyake and Friedman's (2012) argument that different executive measures may tap into different functions. This is an important finding, as it alerts us to be careful about comparing bilingual studies employing different measures. In fact, it may even provide a partial explanation for why the bilingual advantage is not consistently found over studies. We use the term 'partial', as it cannot account for all discrepant findings. For instance, Paap and Greenberg (2013) employed 15 measures, while none of them yielded any bilingual effects. Here, we like to propose that linguistic variables, such as L2 proficiency, play a role. Indeed, the current study found that balanced bilinguals and interpreters made fewer errors than unbalanced bilinguals on both control tasks, indicating superior control. In addition, they were also more skilled at orienting. Again, this could be due to the fact that they had more experience employing cues to select the correct language.

The interpreter advantage

Up until now, only few studies have explored the effects of simultaneous interpreting on cognitive control (e.g. Christoffels et al., 2006; Yudes et al., 2011). Neither of these studies disclosed any inhibitory control advantages, although Yudes et al. (2011) did report better mental flexibility in interpreters. The current study did obtain evidence of an inhibitory advantage for interpreters relative to unbalanced bilinguals. The effect emerged consistently for accuracy, both for the Simon task and the ANT. It is not very clear whether this difference is due to a speed-accuracy trade-off in the unbalanced group (Simon: $r = -.154$, $p = .385$, ANT: $r = -.163$, $p = .357$). Task demands may have contributed to the differences being reflected in accuracy, rather than RT. In the Simon task, participants only had 900 ms to respond after onset of the stimulus, which may have encouraged them to respond quickly but less accurately. In the ANT, the intertrial interval changed constantly, which was for instance not the case in Costa et al. (2008). Our task thus required more attention and focus; possibly similar to the type of attention and focus related to interpreting. This view is supported by Marzecová et al. (2013a&b), who also reported higher accuracy for bilinguals and hypothesised that this advantage was due to the bilingual's ability to efficiently focus attention on the task at hand. Consequently, we do not believe that finding differences on accuracy rather than on RT fundamentally hampers the implications of the results; both measures reflect the ability of sustained attention and control.

All in all, the interpreter advantage is quite remarkable, as our participants were only student interpreters with limited experience; most of them were late L2 learners (82%) and used their L2 less frequently than balanced bilinguals. This suggests that even limited interpreter training induces the same positive effects on cognitive control as early L2 acquisition and frequent L2 use. Nevertheless, it is possible that the interpreter advantage will be more evident in, for instance, cognitive flexibility tasks (Yudes et al., 2011), as some studies claim that interpreting does not involve inhibitory processes after all (Ibáñez, Macizo, & Bajo, 2010), but other cognitive specialisations instead.

The language control advantage

So far, the direct relation between language control and executive control has been an elusive one. Yim and Bialystok (2012) were not able to determine any relation between language switching and non-verbal task switching, while Prior and Gollan (2011; 2013) did. So, what can be the reason for the discrepancy between these results? Prior and Gollan (2011, 2013) included only balanced bilinguals, while Yim and Bialystok analysed balanced and unbalanced bilinguals together. Now, we observed a strong correlation (r = .530) between fluent switching and cognitive control, but only in balanced bilinguals. Thus, a viable explanation may be that the effects are only present in balanced bilinguals, as they are the ones most in need of language control skills.

Unfortunately, our study design does not permit us to make any conclusive assertions about the causal direction of the relation; it is possible that language switching leads to better cognitive performance, but it may also be the other way around. However, as the correlation only occurred in balanced bilinguals, who have more experience with language switching, it seems plausible that it is the practice of language switching that drives cognitive control. Otherwise, one may argue that interpreters or unbalanced bilinguals with better cognitive control should be better language switchers as well.

Implications

The importance of this study is reflected in its three major findings. Firstly, it confirmed the hypothesis of a cognitive control advantage for bilinguals compared with monolinguals. Still, the advantage was not present on every measure of executive functioning, which may explain why studies employing different measures obtain different results. Secondly, this study demonstrated higher accuracy scores for interpreters in both Simon and ANT, hereby substantiating that language control training influences executive control and that this training surpasses the role of other linguistic variables, such as age of L2 acquisition. Thirdly, by ascertaining a correlation between language control and executive control in balanced bilinguals, this study showed that at least within one type of bilingual population, individual differences in language control abilities relate to cognitive advantages. This confirms that the magnitude and nature of any bilingual effects may depend on the typology of the bilingual population under investigation. All in all, this study revealed that both the nature of cognitive control measures and particular bilingual experiences modulate the magnitude of the bilingual advantage.

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