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Inhibitory and attentional control: the interaction between "professional activity" and bilingualism

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Abstract

This study investigates the consequences of bilingualism on inhibitory and attentional control. Findings garnered from studies about the so-called bilingual advantage in such executive functions are still controversial. This investigation tested 40 (20 monolinguals and 20 bilinguals) highly-educated middle-aged (ranging from 36–58 years old) businesspeople in two nonverbal cognitive tasks, the Simon task and the Attentional Network Task (ANT). No significant statistical differences were found in the interference effect between the groups, nor was there a bilingual advantage in any of the three attentional networks. The results suggest that variables such as level of education and professional activity might compete with the bilingual advantage, acting as possible research confounds.

Keywords: Cognition, bilingualism, executive functions, inhibitory control, attention

Background

It has been a while since the number of bi/multilingual speakers has outnumbered the total of monolingual speakers on the globe. In fact, in 1998, over two thirds of the world population was bilingual (Baker and Jones 1998), and that number has increased significantly over the last two decades. According to the Associated Press (2001), 66 % of the world's children are raised bilingual. Never before did so many people make use of different languages in their everyday life as they do now, for professional and academic reasons, or simply out of cultural interest.

The ability to speak more than one language has always been intriguing, and has led researchers to conducting investigations whose findings suggest that bilingualism can actually enhance some of bilinguals' cognitive processes throughout life (e.g. Bialystok et al. 2004; Bialystok et al. 2005a, b). Those processes are called "executive functions" (EFs), an umbrella term comprising a wide range of cognitive processes and behavioral competencies (Chan et al. 2008) such as: verbal reasoning, problem-solving, planning, sequencing, the ability to sustain attention, resistance to interference (inhibition), utilization of feedback, multitasking, cognitive flexibility, and the ability to deal with novelty. According to Alvarez and Emory (2006), indications have been found for the sensitivity but not for the specificity of EF measures to frontal lobe functioning, signaling the involvement of both frontal and non-frontal brain areas. Regarding language production in bilinguals, Abutalebi and Green (2007) point out the involvement of cortical and subcortical structures that make use of inhibition to resolve lexical competition and to select the intended language. The single network mediating the representation and the control of a person's L1 and L2 is made up of the following: the prefrontal cortex, the anterior cingulate cortex, the basal ganglia and the inferior parietal lobule.

Bilingualism, however, has not always been seen as beneficial to human cognition. The first studies carried out in the late 19th and early 20th centuries found that bilinguals performed poorly in tests which measured their IQ (Darsie 1926; Saer 1923), and such an idea lingered along the first decades of the 20th century. Only in the 1960s did bilingualism acquire a positive status, when Peal and Lambert's work (1962) indicated that Canadian bilingual children had a better performance than monolingual ones, especially on tests requiring symbol manipulation and reorganization.

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In the last two decades or so, bilingualism has become a point of interest for cognitive sciences such as psycholinguistics and neurolinguistics. A substantial number of studies have consistently found significant cognitive differences between bilinguals and monolinguals in some age groups. Regarding disadvantages, all related to linguistic performance, bilingual children usually have a smaller vocabulary in each of their languages – although their total vocabulary is bigger than that of a monolingual child – and are also slower in lexical access (Bialystok and Feng 2011). The same is true for bilingual adults and the elderly. They all tend to be slower in picture naming tasks, to obtain lower scores on verbal fluency tasks (Gollan et al. 2002), to show slower semantic fluency (Gollan et al. 2002), and to experience more interference in lexical decision (Ransdell and Fischler 1987). Besides, bilingual speakers are more susceptible to tip of the tongue states, (Gollan and Acenas 2004) which consist of "a temporary inaccessibility of information that one is sure exists in long-term memory and is on the verge of recovering" (Abutalebi and Green 2007, p. 250).

However, most of the differences tend to be advantageous and are related to cognitive performance. Bilingual children, for example, outperform monolinguals when faced with problems containing conflicting or misleading cues, especially on conditions in which the demands for inhibitory control (the ability one has to deliberately inhibit dominant, automatic, or prepotent responses when it is necessary; Miyake et al. 2000) are high (Martin-Rhee and Bialystok 2008). Furthermore, they show greater mental flexibility (Peal and Lambert 1962), enhanced metalinguistic awareness (Cummins 1978), and increased creativity (Kessler and Quinn 1987). The same is true for bilingual adults, especially when it comes to nonverbal tasks demanding higher executive control skills. In the Simon task (Bialystok et al. 2004), for example, bilinguals have shorter reaction times (RTs) for both congruent and incongruent trials (Bialystok et al. 2004; Bialystok et al. 2005a, b; Bialystok 2006), and in the Attentional Network task (ANT) (Fan et al. 2002), bilinguals usually show faster RTs, a smaller conflict effect and smaller switch costs (Costa et al. 2008).

As a whole, the so-called bilingual advantage corresponds not only to a greater inhibitory and attentional control, but also to a 4.1-year delay on the onset of the symptoms of dementia like Alzheimer's (Bialystok et al. 2007; Craik et al. 2010), given that bilingualism also promotes cognitive reserve, i.e. the protective effects of experience against cognitive decline with aging (Bialystok 2009). Such advantage is closely intertwined with the concept of code-switching – a complete shift to another language for a word, phrase or sentence (Grosjean 2001).

Grosjean (2001, p. 2) explains that "the state of activation of the bilingual's languages and language processing mechanisms, at a given point in time, has been called the language mode". In the monolingual language mode, a bilingual person partially deactivates one language, whereas in the bilingual language mode, a base language is chosen, the other language is activated and called on in the form of code-switches and borrowings. Code-switching demands a greater executive and attentional control, and probably has strong effects on nonverbal tasks as well. That is due to the fact that language control in bilinguals relies on a neural system shared with more general cognitive control processes, that is, the dorsal anterior cingulate cortex, which is responsible for detecting and aiding the resolution of conflicts not only in the verbal, but also in the nonverbal domain (Abutalebi et al. 2012).

Green (1998) designed the Inhibitory Control Model (the IC Model) in order to explain bilinguals' ability to speak one language rather than another, to code-switch, and also to translate between the languages spoken. If Green's model is right, bilinguals are able to control their two language systems by inhibiting potential competitors for production at the lemma level, by virtue of their language tags. Each lexical concept is associated with a lemma that specifies its syntactic properties, leading to the activation of an associated word form.

Inhibitory control and attention are the EFs chosen for the present study because although inhibitory control in bilinguals has been extensively investigated, the results are still controversial, for a lot of studies have not been able to replicate the bilingual advantage found by Bialystok et al. (2004), as pointed out by Hilchey and Klein's (2011) and Paap and Greenberg's (2013) reviews. Regarding attention, this study used a model composed by three networks, namely, executive control, orienting and alerting networks. The three attentional networks have been the focus of several studies including bilinguals (e.g. Costa et al. 2008, 2009; Hernandez et al. 2010; Marzecová et al. 2013; Videsott et al. 2012), and the bilingual advantage seems not to be restricted only to the executive control network.

The three attentional networks have been traditionally understood as independent from one another (Fan et al. 2002), although researchers acknowledge the fact that they cooperate and work closely together. The executive control network includes the monitoring and resolution of conflict between computations in different neural areas, such as planning or decision making, error detection, conditions judged to be difficult or dangerous, regulation of thoughts and feelings, and the overcoming of habitual actions (Raz and Buhle 2006). It can be measured by tasks such as the Simon task (Bialystok et al. 2004) and the flanker, part of the ANT task (Fan et al. 2002), for they offer an incompatibility between the dimensions of the stimulus and the response, as shall be described in the *Instruments* section.

The orienting network corresponds to the ability to select specific information from among multiple sensory stimuli. It can be measured by shorter RTs in trials where a spatial cue is offered, giving information on the location. There are two types of orienting: 1) exogenous orienting, when the flash of a cue automatically captures attention to a specific location, and 2) endogenous orienting, when a central arrow points to one of two lateralized target presentation locations (Raz and Buhle 2006). In the ANT task, responses to spatial cued trials are subtracted from responses to center cued trials, allowing us to measure the efficiency of the orienting network (Costa et al 2008).

The alerting network refers to the ability to increase and maintain response readiness in preparation for an impending stimulus. There are two types of alertness: phasic alertness (task specific) and intrinsic alertness (a general cognitive control of arousal). The efficiency of this network can be measured by the ANT task by subtracting the responses to trials that offer a temporal cue from those that do not (Raz and Buhle 2006).

Considering the issues above, this experimental study of empirical nature investigated middle-aged monolinguals and bilinguals matched in age, education and profession (businesspeople), in two nonverbal cognitive tasks. The Simon task (Bialystok et al. 2004) was used for testing inhibitory control and attention, while the ANT task (Fan et al. 2002) assessed the executive control network (with an inhibitory control component) and the alerting and orienting networks. The purpose of focusing on these groups of participants was twofold, replicating some of the experiments conducted previously with another population of participants regarding: 1) age; and 2) profession. Concerning age, the findings on the so-called bilingual advantage in such EFs are still controversial, and we perceived a lack of studies on the effects of bilingualism regarding middle-aged adults, as compared to the considerably high number of studies and robust findings on the bilingual advantage among other age groups, such as children and elderly people. Concerning profession, businesspeople are naturally faced with strong cognitive demands on a daily basis while negotiating and making online administrative and financial decisions. They are required to be extremely objective when it comes to critical decisions, being able to focus on tasks and problems and ignoring distracting stimuli, not allowing themselves to be influenced by minor issues that are not urgent. Thus, their problem solving, multitasking and inhibitory control skills are constantly demanded. As a result, the cognitive demands of their professional activity could act as a natural competitor with bilingualism in strengthening these EFs. It is important to underscore the fact that no previous work has addressed such population in any of these regards, nor has the ANT task been applied to such age group with the same format and purposes. Furthermore, what seems to be unique about this specific population is the fact that it must be the sample with the highest level of education, at least among Brazilian studies, and that alone deserves careful investigation.

Method

Participants

There were 40 participants in this experiment, divided into two groups, 20 monolingual and 20 bilingual businesspeople (managers or directors) working in different companies located in Porto Alegre, Canoas, São Leopoldo, Portão, Pelotas and Rio Grande, in Rio Grande do Sul, Brazil. They were matched in age (36 – 58) and education (they all had at least one university degree), and were all right-handed. There were 15 male and 5 female monolinguals, mean age 47.2 years and educational level 18.6 years; and 14 male and 6 female bilinguals, mean age 48.1 years and educational level 18.4 years. There were more men than women because direction and management activities in Brazil seem to be still mostly performed by men. Thirty-eight participants had Brazilian Portuguese as L1 (two bilinguals had German/Pomeranian or Italian as L1), but they were all born and raised in Brazil. Participants' L2 varied (15 spoke English as L2, three spoke Spanish, and two spoke Brazilian Portuguese). The bilinguals use their L2 for different purposes and in different situations: in frequent or sporadic business meetings and trips, conference calls via Skype, phone calls and sometimes at home or travelling with friends and family. The study was approved by the Ethics Committee of UCPel (RS), Brazil (document nr. 16028/2012). Most of the participants were contacted, interviewed and tested at their work places by the same examiner using the same equipment and instructional protocols. The participants were asked about video game use (the ones who used to be or still were regular players were ruled oud) for it promotes strong speed advantages to answer to the stimuli to such a degree that bilingualism can do little to further improve the RTs measured by the tasks (Bialystok et al. 2005a, b). However, due to their professional activity, all of them are very familiar with computers. No instruments were used to measure social economic status, but it was assumed to be equivalent among them, considering their level of education and jobs. No reward was offered to them, who were invited to be part of an experiment which would investigate the cognitive differences resulting from the use of an L2 on a regular basis.

Apparatus

The participants were placed in a quiet room where they could concentrate to perform the tasks. The examiner started each interview with a participant signing a Free and Informed Consent Form, followed by a Screening Questionnaire and a Linguistic Background Questionnaire (Zimmer and Bonini 2008), to be answered orally, question by question. The former questionnaire contained questions about personal information such as handedness, level of education, history of health problems and medicine use. Participants who followed a prescription of antidepressants or anxiolytics or anything else that could interfere with the results of the research were ruled out at this stage. The latter contained questions about their social life, professional activity, the languages spoken, as well as travelling and intercultural experience. Questions regarding the age and context of acquisition of their L2/L3, and the amount and frequency of use of their language(s) regarding speaking, reading and writing allowed us to classify the participants as monolinguals or bi/multilinguals. Neither fluency nor proficiency were the key issues to classify them as bi/multilinguals, but the regular use of two or more languages (Grosjean 2010). Only one participant was ruled out after the Screening Questionnaire, while nobody was ruled out after the Linguistic Background Questionnaire. The examiner filled out the questionnaires, which were then followed by two computerized cognitive tasks. The data concerning such tasks were collected with a Microboard Netslim 10" netbook, containing Windows XP, and the software E-prime 1.2.

Instruments

Simon task

The Simon task (Bialystok et al. 2004) is used to measure the effects of the EFs inhibitory control and attention, aspects of processing which decline with aging. It is "based on stimulus–response compatibility and assesses the extent to which the prepotent association to irrelevant spatial information affects participants' response to task-relevant nonspatial information" (Bialystok et al. 2004, p. 291).

The design is as follows: what the participants see on the screen is a sequence of stimuli in the shape of colored rectangles (brown, blue, yellow, pink, green and red) that are presented on either the left or the right side of a computer screen, arranged in four different conditions: center/2 colors, lateral/2 colors, center/4 colors and lateral/4 colors. Each color is associated with a response key that is on one of the two sides of the keyboard, aligned with the two stimulus positions. On congruent trials, the key that is the correct response for that color is on the same side as the stimulus, while on incongruent trials, the correct response key is on the opposite side. Participants must press the right key as quickly and accurately as possible, since level of accuracy and RTs are measured.

In the Simon task, we can calculate the Simon effect. According to Lu and Proctor (1995, p. 174), "the Simon effect refers to the fact that responses are faster when the stimulus location corresponds to the location of the assigned response than when it does not". It is obtained by subtracting responses to congruent trials from those to incongruent ones. Since congruent trials offer no conflict, i.e., no irrelevant spatial information, faster RTs are expected, resulting in positive RTs for Simon effects. When negative RTs are obtained, though, one could assume that participants have learnt to deal with the conflict caused by the irrelevant location information, having internalized the task rules.

ANT task

The ANT task was developed by Fan et al. (2002). It combines a cue reaction time task (Posner 1980) and a flanker task (Eriksen and Eriksen 1974). With the ANT, we can assess the three attentional networks. According to Costa et al. (2008, p. 65), this task "is especially appropriate to assess potential differences between monolinguals and bilinguals, since it relies minimally on linguistic and memory processes that may interact with bilingualism", and its multidimensionality allows drawing a set of interesting predictions in terms of the potential conditions that may be affected by bilingualism.

Participants are instructed to press as quickly and accurately as possible the right button of the mouse (located at the frontal part of the computer keyboard, in a fixed position, allowing for stability of movements) with their right hand if a central arrow points to the right (→) and the left button of the mouse with their left hand if it points to the left (←). The central arrow is presented below or above a fixation point (+) with two flanker arrows pointing to the same or different direction than the target arrow (see Fig. 1a). There is also a neutral condition. If they point to the same direction it is a congruent trial, if not, it is an incongruent one. Responses tend to be slower for incongruent trials, reflecting the time required to resolve the conflict between the target stimulus and the flanker information which must be ignored, and so assessing the executive control network.

To assess the alerting network, a cue in the form of an asterisk (*) is presented before the target stimulus. Responses tend to be faster if the target is preceded by an alerting cue. For the orienting network to be assessed, the cue is presented (*) to signal the position in the screen where the target stimulus is going to appear. Again, responses tend to be faster when there is a cue signaling where the target will appear, below or above the fixation point.

Procedures

Simon task

The participants completed four conditions in one of four preset orders consisting of 24 trials per condition,

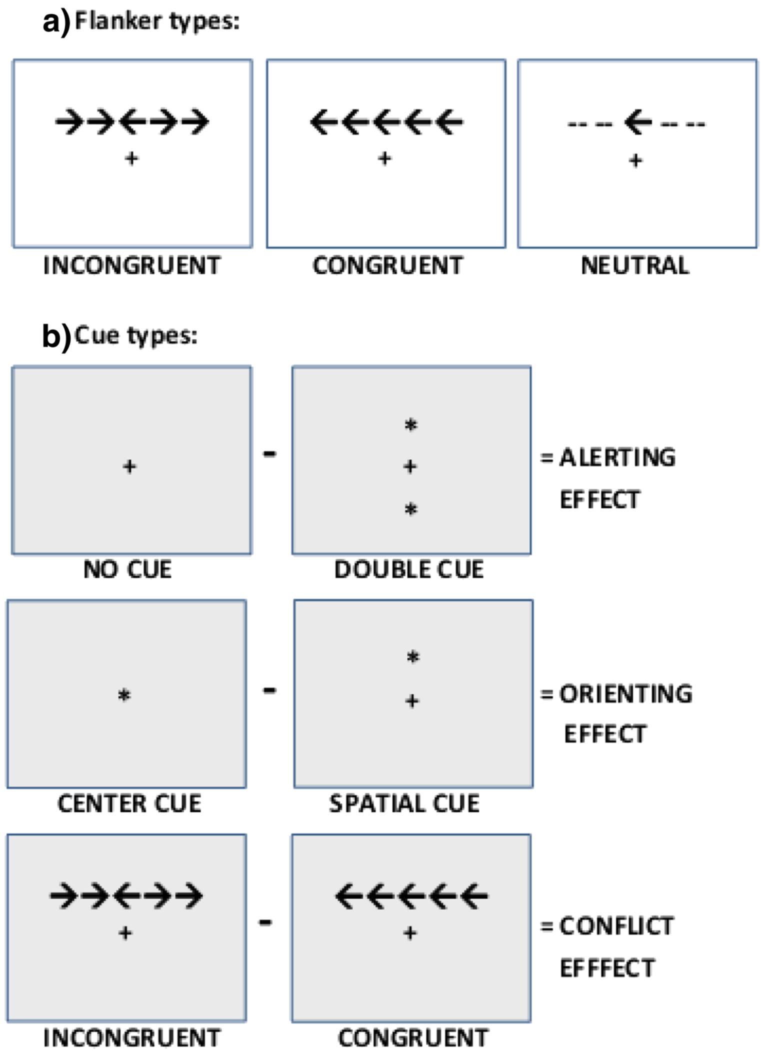

Fig. 1 The Attentional Network Task (ANT): experimental design: **a** Flanker types; **b** Cue types

which were all then repeated in the reverse order, producing 48 trials for each of them. Each condition was preceded by a set of practice trials, four for the 2-color conditions and eight for the 4-color conditions, which were identical to test trials. Participants had to complete all eight practice trials correctly to move on to test trials; if not, the program recycled until all practice trials were completed successfully.

In the 2-color conditions, participants were instructed to press 1 when they saw a blue rectangle and 0 when they saw a brown one. In the 4-color conditions, participants were instructed to press 1 when they saw a green or a pink rectangle, 0 when they saw a red or a yellow one. Trials began with a sound (a computer "bing") and a fixation cross (+) that appeared in the center of the screen for 300 ms. Immediately after the cue, the stimulus appeared and remained on the screen until a response was made. The response clock started at the onset of the stimulus. The fixation cross and the sound reappeared 500 ms after the response to signal the next trial. When the stimuli were presented in lateral positions, the order of trials was randomized and divided equally between congruent and incongruent items.

ANT task

The actual experiment was preceded by a set of 24 practice trials (about 2 min). Then, participants took three experimental blocks of trials presented in random order (5 min each). There were two within factors, "Cue Type" (no cue, center cue, double cue, spatial cue), and "Flanker Type" (neutral, congruent, incongruent). The crossing of those values resulted in 12 experimental conditions. Each condition was represented by 8 trials in each block, leading to a total of 96 trials per block. Participants were instructed to rest between blocks. The event presentation was as follows: (a) the fixation point

(+) appeared on the center of the screen for 400 ms; (b) a cue (*) was presented for 100 ms; (c) a fixation period for 400 ms after the cue; (d) the target arrow and the flankers were presented simultaneously until participant's response or up to 1700 ms; then, (f) the target and flankers disappeared after response and the next trial began. The fixation cross appeared at the center of the screen during the whole trial (Costa et al. 2008; Fan et al. 2002). The final scores were obtained by subtracting: RT no cue from RT double cue (Alerting effect); RT center cue from RT spatial cue (Orienting effect); and RT incongruent from RT congruent (Conflict effect) (see Fig. 1b).

Design

The participants performed the Simon task (Bialystok et al. 2004), and the ANT task (Fan et al. 2002). In both, "RT" and level of "Accuracy" were taken as dependent variables, and "Language Group" (monolingual/bilingual) was taken as an independent variable. In order to choose the appropriate statistical tests, we contrasted the normality hypothesis for all the pairs of samples with the Shapiro–Wilk and the Kolmogorov-Smirnov tests. Since we were dealing with independent factors, we also used the Levene test to see the homogeneity of variance. Results indicated that some of our variables did not show normality or homogeneity and so were measured by non-parametric tests such as the Mann-Whitney, while others could be measured by Independent Samples t-tests. Because we were dealing with second language research, we used a p-value below 0.05 as a cut-off point for all the statistical tests.

Results

Simon task

The mean RTs for the correct trials and accuracy scores in each of the Simon conditions are presented in Table 1. Non-parametric tests were run for all the accuracy scores because our variables did not show normality or homogeneity. Mann-Whitney tests revealed no significant statistical differences between the groups in most conditions, since both language groups made very few errors in all four conditions, with the mean percentage of errors ranging from 0 to 4 % – bilinguals (2 %) and monolinguals (1 %). The only significant statistical difference in terms of accuracy was the lateral congruent 2-color condition, in which monolinguals outperformed bilinguals ($Z = -2.12$, $p = .03$) (see Table 1).

The RTs for the center 2-color and 4-color conditions, and the lateral congruent 2-color and 4-color conditions were also examined with Mann-Whitney tests. Significant statistical differences were found in the center 4-color condition, favoring bilinguals ($Z = -2.07$, $p = .04$), and in the lateral congruent 2-color condition, also favoring bilinguals ($Z = -2.58$, $p = .01$). The RTs for the lateral incongruent 2-color and 4-color conditions were examined with Independent Samples t-tests, with no significant statistical differences.

Regarding the Simon effect (also shown in Table 1), no significant statistical differences were found, as indicated by an Independent Samples *t*-test for the 2-color Simon effect, and by a Mann-Whitney test for the 4-color Simon effect. As a matter of fact, both bilinguals and monolinguals had faster RTs in incongruent trials than in congruent ones, resulting in negative RTs for the Simon effects for both groups in the 2- and 4-color conditions, thus revealing no interference effects.

ANT task

The mean RTs (ms) for the correct trials and error rates (%) in each of the ANT conditions are presented in Table 2. The error rates (see Table 2b) ranged from 0 to 4 % – bilinguals (1 %) and monolinguals (2 %) – for which Mann-Whitney tests were run, revealing no significant statistical differences between the groups. Mann-Whitney tests were run for two RT scores: the spatial cue congruent condition, with no differences between the groups, and the double cue incongruent condition, revealing significant statistical differences favoring bilinguals ($Z = -2.27$, $p = .02$) (see Table 2a). All the other RT scores were examined with Independent Samples t-tests, but no significant statistical differences were found.

Table 1 Mean Reaction Time (RT) (in Milliseconds) and Accuracy (ACC) for Simon Task and Language Group

Language group	No. of colors	Center		Lateral				Simon effect
				Congruent		Incongruent		
		RT (ms)	ACC (%)	RT (ms)	ACC (%)	RT (ms)	ACC (%)	
Monolingual								
(20)	2	570.67 (105.47)	0.99 (0.02)	648.04 (108.94)	0.98* (0.05)	578.85 (106.72)	1.00 (0.01)	-69.18
	4	711.47 (174.72)	0.98 (0.04)	698.77 (160.12)	0.99 (0.02)	669.76 (118.64)	1.00 (0.01)	-29.01
Bilingual								
(20)	2	517.44 (130.55)	0.98 (0.04)	571.57* (128.82)	0.96 (0.05)	533.90 (113.69)	0.99 (0.04)	-37.67
	4	622.20* (159.64)	0.97 (0.04)	634.13 (129.10)	0.96 (0.05)	630.20 (157.08)	0.99 (0.02)	-3.93

Note. Source: Study data. Standard deviations are in parentheses
*Statistically significant differences ($p < 0.05$)

Table 2 Mean Reaction Times (in Milliseconds) (a) and Error Rates (%) (b) for Bilingual and Monolingual Participants Broken for Flanker Type and Cue Type

	Flanker						
	Congruent		Incongruent		Conflict effect		
	Bil	Mon	Bil	Mon	Bil	Mon	Δ Bil-Mon
(a) Cue							
None	595 (85)	621 (69)	699 (119)	742 (74)	104	121	17
Double	549 (77)	571 (55)	668* (110)	725 (60)	119	154	35
Center	572 (96)	593 (66)	682 (118)	744 (86)	110	151	41
Spatial	511 (76)	538 (70)	591 (107)	654 (93)	80	116	36
Allerting effect	46	50	31	17			
Δ Bil-Mon		4		14			
Orienting effect	61	55	91	90			
Δ Bil-Mon		6		1			
(b) Cue							
None	0.01 (0.02)	0.01 (0.02)	0.02 (0.03)	0.03 (0.04)	0.01	0.02	0.01
Double	0.00 (0.01)	0.00 (0.01)	0.02 (0.03)	0.04 (0.04)	0.02	0.04	0.02
Center	0.01 (0.02)	0.01 (0.02)	0.02 (0.03)	0.04 (0.07)	0.01	0.03	0.02
Spatial	0.00 (0.01)	0.01 (0.02)	0.02 (0.03)	0.02 (0.05)	0.02	0.01	0.01
Allerting effect	0.01	0.01	0	-0.01			
Δ Bil-Mon		0		-0.01			
Orienting effect	0.01	0	0	0.02			
Δ Bil-Mon		0.01		0.02			

Note. Source: Study data. Standard deviations are in parentheses
*Statistically significant differences ($p < 0.05$); Bil (Bilingual); Mon (Monolingual);
Δ Bil-Mon: the result of the difference between Bilinguals and Monolinguals

Both bilinguals and monolinguals obtained higher RTs in all the incongruent conditions, resulting in positive RTs for Conflict effects, revealing the expected difficulty to respond to trials with incongruent flankers. Even though bilinguals (103 ms, $SD = 47.30$) suffered less interference than monolinguals (135 ms, $SD = 72.48$) in terms of Conflict effect, a Mann-Whitney test revealed no significant statistical differences between the groups. The same is true about the Alerting effect, bilinguals (44.25 ms, $SD = 26.00$) and monolinguals (40.37 ms, $SD = 27.60$), and about the Orienting effect, bilinguals (67.32 ms, $SD = 28.33$) and monolinguals (62.74 ms, $SD = 28.53$). Also for these two effects, Independent Samples t-tests revealed no significant differences between the groups.

Discussion

Simon task

There was only one significant statistical difference in accuracy favoring monolinguals, but accuracy is not the focus of our study. Concerning RTs, bilinguals were faster than monolinguals in two conditions, the center 4-color and the lateral congruent 2-color conditions. However, it is important to say that central and lateral congruent conditions are neutral for they do not offer any conflict (i.e. no irrelevant spatial information). Bilinguals were expected to be faster in both congruent and incongruent trials, or to show an advantage in the Simon effect. However, both bilinguals and monolinguals presented faster RTs in incongruent trials, resulting in negative RTs for the Simon effect, but with no significant differences. In face of negative RTs, one could claim that the Simon effect is null. As Bialystok (2004, p. 291) points out, “numerous studies with this task have confirmed that the irrelevant location information results in reliably longer reaction times (RTs) for incongruent items”. Such tasks are very sensitive to the parameters in the experiment, such as timing, stimuli characteristics, etc. However, negative RTs for the Simon effect have been found in several studies conducted in Brazil using different versions of the Simon task (e.g., Bandeira 2010; Finger et al. 2011; Kramer 2011; Martins 2010; Pinto 2009) to different age groups, with different types of bilinguals, which means that such pattern deserves a more careful investigation, especially because the design of the Simon task applied to our participants, and in some of the other Brazilian studies mentioned above, is the same one used by Bialystok et al. (2004) in Study 2.

In Bialystok et al. (2004), a bilingual advantage in the interference effect was found in Studies 1 and 2 for both middle-aged and old-aged participants, being more pronounced for the younger groups, showing that bilingualism "did not attenuate the age-related decline in inhibitory effectiveness" (Bialystok et al. 2004, p. 293), as the authors had expected. Other studies using the Simon task with different age groups have not been able to replicate Bialystok et al.'s results regarding the interference effect: children (Bialystok et al. 2005a, b; Martin-Rhee and Bialystok 2008); and young adults (Bialystok 2006; Bialystok et al. 2005a, b; Humphrey and Valian 2012; Paap and Greenberg 2013). Moreover, countering Hilchey and Klein's 2011 statement that older aged groups have been understudied, there are various Brazilian studies, such as Pinto's (2009) and Kramer's (2011), including our own, addressing middle-aged adults, and again Pinto's and Kramer's studies, plus Billig's (2009) and Martins's (2010) studies addressing elder individuals, which have not been able to replicate Bialystok et al.'s (2004) results either.

We cannot ignore, in face of so many results pointing to no bilingual advantage in the interference effect, that the massive impossibility to replicate Bialystok et al.'s 2004 results might rely on the fact that their study might present methodological inconsistencies regarding demographic factors, once they included populations with different nationalities and certainly dramatic cultural differences, and the data were even collected in different countries. Subsequent studies have taken more appropriate measures to minimize as much as possible such differences, including type of bilingualism and social economic status. The latter, as reinforced by Morton and Harper (2007) and Mezzacappa (2004), might have an impact on the bilingual advantage, and also covary with executive ability, for higher social economic status tends to be associated with better performance on measures of cognitive functioning.

Our study, contrary to Bialystok et al.'s (2004), investigated a more homogeneous sample, since all the participants were born and raised in Brazil, were extremely familiar with computers and were controlled for video game use. Another differing variable between Bialystok et al.'s 2004 study and ours refers to the instruments used to select the participants. While they used instruments such as PPVT–III, Catell Intelligence task, Digit Span tasks, we used the screening and the linguistic background questionnaires (Zimmer and Bonini 2008). These differences regarding control of variables may account for the difficulty found by us and other researchers to replicate Bialystok et al.'s findings. Furthermore, it is important to bear in mind the fact that no other study included a homogeneous professional group with such strong cognitive demands, nor with such high levels of education. Both "profession" and "level of education" could be the key variables interfering with the bilingual advantage in this particular study.

ANT task

Contrary to the results in the Simon task, in the ANT task, incongruent trials were more difficult than congruent ones, resulting in longer RTs for both groups. The same is true for alerting and orienting cues: trials with no cues were more difficult than the ones with double cues; and trials with center cues were more difficult than the ones with spatial cues. However, it is important to point out that such conclusions are based on the observation of the averages, once we did not run tests within participants to compare their performance regarding the different types of trials, that being one of the limitations of our study. Regarding the tests between participants, no significant statistical differences were found in any of the three attentional networks.

Concerning the three effects measured, it is important to underscore that no study has ever reported a bilingual advantage on the Orienting effect, regardless of age group. However, in Costa et al. (2008), who investigated a population of young adults, a bilingual advantage was found for both Conflict and Alerting effects. The same age group was also investigated in Costa et al. (2009), but no bilingual advantage was found for the Alerting effect. The only bilingual advantage found was for Conflict effect, but it was restricted to Block 1 of the 75 % congruent version. On this matter, it is important to highlight that Costa et al. (2008) and Costa et al. (2009) used different percentages of congruent trials. Costa et al.'s 2008 experiment was divided equally between neutral, congruent and incongruent trials (which was replicated in the present study). However, Costa et al.'s 2009 two experiments were divided as follows: the first one used two low-monitoring versions (92 and 8 % congruent trials), while the second one used two high-monitoring versions (50 and 75 % congruent trials). Such differences in number of congruent trials, also pointed out by Hilchey and Klein (2011), could serve as an explanation for the inconsistency of results found between these two studies, which focused on the same age group and similar bilinguals (early and highly-proficient), but the authors themselves claim they still cannot explain their own contrasting results (Costa et al. 2009, Appendix C). Concerning other age groups, the study by Carlson and Meltzoff (2008), which used the children's version of the ANT task, assessed only the executive control network, but RTs for the ANT task results are not provided by the authors, thus it is not possible to assume a bilingual advantage regarding such effect in this age group.

Conclusion

This study was an attempt to replicate previous experiments on the so-called bilingual advantage concerning inhibitory and attentional control in two nonlinguistic interference tasks (the Simon task and the ANT task), and to contribute to the number of studies of this nature by including middle-aged participants as well. We also sought an effect of the variable "Profession" as a possible natural competitor with bilingualism in strengthening such EFs. Our results seem to corroborate our assumptions, since no bilingual advantage was found whatsoever in the interference effect or in any of the three attentional networks for this professional group. However, in order to reinforce that, it is advisable that in future studies a control group with the same age and level of education but a different profession be included to be compared to the businesspeople in both tasks. Furthermore, it is important to keep in mind that there is still a lot of controversy (Hilchey and Klein 2011; Paap and Greenberg 2013) concerning all the findings regarding the effects of bilingualism on cognition in studies both abroad and in Brazil. Thus, further studies should be extremely thorough regarding their bilingual and monolingual populations in order to avoid methodological inconsistencies.

Competing interests
The authors declare that they have no competing interests.

Authors' contributions
LRR carried out the experimental studies, the statistical analysis and drafted the manuscript. All authors read and approved the final manuscript.

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