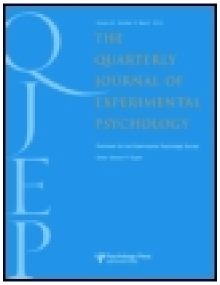

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Ageing and bilingualism: Absence of a ““bilingual advantage”” in Stroop interference in a nonimmigrant sample

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Previous research has found an advantage for bilinguals relative to monolinguals on tasks of attentional control. This advantage has been found to be larger in older adults than in young adults, suggesting that bilingualism provides a buffer against age-related declines in executive functioning. Using a computerized Stroop task in a nonimmigrant sample of young and older monolinguals and bilinguals, the current investigation tried to replicate previous findings of a bilingual advantage. A bilingual advantage would have been demonstrated by smaller Stroop interference (i.e., smaller increases in response time for incongruent than for neutral trials) for bilinguals than for monolinguals. The results showed that bilingual young adults showed a general speed advantage relative to their monolingual counterparts, but this was not associated with smaller Stroop interference. Older adults showed no effect of bilingualism. Thus, the present investigation does not find evidence of a bilingual advantage in young or older adults and suggests limits to the robustness and/or specificity of previous findings.

Keywords: Ageing; Bilingualism; Stroop interference; Bilingual advantage.

Recent investigations suggest that the extensive use of the executive control processes required for manipulating two languages in lifelong bilinguals may provide them with an advantage on tasks of attentional control (Bialystok, 2006; Bialystok, Craik, Klein, & Viswanathan, 2004; Bialystok, Craik, & Ryan, 2006; Costa, Hernández, Costa-Faidella, & Sebastián-Gallés, 2009; Costa, Hernández, & Sebastián-Gallés, 2008; Martin-Rhee & Bialystok, 2008) such as the Stroop task (Bialystok, Craik, & Luk, 2008; Zied et al., 2004). Evidence for this comes from studies in children (e.g., Martin-Rhee & Bialystok, 2008), young adults (e.g., Bialystok, 2006; Costa et al., 2009;

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Costa et al., 2008), and older adults (e.g., Bialystok et al., 2004; Bialystok et al., 2008; Zied et al., 2004). Given the well-documented declines in cognition that have been associated with ageing (Craik & Salthouse, 2008), these effects of bilingualism suggest that proficiency in a second language may provide a buffer against such age-related cognitive declines. Specifically, language experience may confer an advantage on non-language-specific cognitive mechanisms. The goal of the present investigation was to replicate previous findings of a bilingual advantage in a sample of highly proficient English/French young and older bilinguals who were equated on sociocultural factors to a greater extent than in previous studies.

In the classic Stroop task (Stroop, 1935), participants named the ink that a colour word was printed in when the ink colour and the word did not match (e.g., saying "red" in response to the word *blue* printed in red ink) and named the colour of solid squares. It was found that it took longer to name the colour of an incongruent colour word than to name the colour of a solid square. Since the publication of Stroop's (1935) seminal paper, the Stroop effect has been extensively studied and has proven to be a highly robust effect (for review, see MacLeod, 1991).

Several theories have been proposed to explain the Stroop interference effect, with varying ability to account for the empirical findings (see MacLeod, 1991). We take the position that Stroop interference results from competition between word reading and colour naming, and that the dominant skill of word reading must be suppressed/inhibited in order to correctly name the incongruent colour of the print. This process has been referred to as interference suppression—that is, the filtering out of irrelevant information in the environment (Bialystok et al., 2008; Bunge, Dudukovic, Thomason, Vaidya, & Gabrieli, 2002). Thus, greater Stroop interference corresponds to weaker interference suppression.

In the current study, the effects of ageing and bilingualism on Stroop interference were investigated. A dominant view in the cognitive ageing literature is that declines in inhibition underlie age-related changes in cognition (Hasher & Zacks, 1988; Zacks & Hasher, 1997). According to this hypothesis, ageing is associated with a decline in inhibitory control that allows irrelevant information to enter working memory and to receive sustained activation. Consistent with this hypothesis, the Stroop effect has been found to be greater in older adults than in young adults. Cohn, Dustman, and Bradford (1984) found that healthy older adults demonstrated greater interference than younger adults, and Houx, Jolles, and Vreeling (1993) showed that this difference remained even when biological life events (e.g., exposure to neurotoxic factors, mild head injuries) were controlled for. Others have found that the greater interference effect in older adults is maintained despite practice with the stimuli (Davidson, Zacks, & Williams, 2003), is present when stimulus orientation is manipulated (Weir, Bruun, & Barber, 1997), and is associated with decreased activation in dorsolateral prefrontal and parietal cortices, more extensive activation of temporal cortex, and increased sensitivity of the anterior cingulate cortex to incongruent colour information (Milham et al., 2002). Although the effect is well established, its cause is more controversial. Some authors have argued that age-related changes in sensory processing (i.e., deterioration of colour vision; Ben-David & Schneider, 2009) rather than a decline in inhibition underlie the effect.

Recently, there has been interest in the effect of bilingualism on Stroop performance. It has been suggested that the management of two languages in bilinguals requires general executive control processes, such as attention, inhibition, monitoring, and switching (see Bialystok, 2007). Specifically, it is well documented that the two languages of a highly proficient bilingual are simultaneously active, even when the individual is engaged in a single language (e.g., Blumenfeld & Marian, 2007; de Bruijn, Dijkstra, Chwilla, & Schriefers, 2001; de Groot, Delmaar, & Lupker, 2000; Dijkstra, Grainger, & van Heuven, 1999; Dijkstra, Timmermans, & Schriefers, 2000; Kerkhofs, Dijkstra, Chwilla, & de Bruijn, 2006; Kousaie & Phillips, 2011a; Libben & Titone, 2009; Marian, Spivey, & Hirsch, 2003; Paulmann, Elston-Güttler, Gunter, & Kotz, 2006; van Heuven, Schriefers, Dijkstra, & Hagoort, 2008), creating circumstances unique to bilinguals whereby executive control is required to manage the two language systems. When a bilingual is using one language, attentional mechanisms are required to maintain focus on the target language and reduce interference from the nontarget language, which leads to extensive practice in bilinguals, but not in monolinguals (Bialystok, 2007; Bialystok & Craik, 2010).

It has been hypothesized that the increased use of these mechanisms in bilinguals results in executive control functions that are "more durable, more efficient and more resilient" (Bialystok, 2007, p. 220). Consequently, it has been suggested that these functions develop earlier and decline later in bilinguals than in monolinguals. The rationale is that attentional control tasks (e.g., the Stroop task) share processing demands similar to those required to manage two languages, such as selective attention to target information, inhibition of irrelevant information, and switching (Bialystok et al., 2004), and, therefore, bilinguals demonstrate an advantage relative to monolinguals on such tasks as a result of extensive practice.

The majority of the evidence for a bilingual advantage comes from the Simon task (Simon & Rudell, 1967). In this task, participants are presented with stimuli that can vary along two dimensions; however, responses are based on one dimension while the other dimension is irrelevant for task performance. For example, participants may be presented with squares that can be red or blue and presented on either side of a computer monitor. Responses are made based on the colour of the stimulus using two lateralized buttons. This creates both congruent and incongruent trials depending on whether the correct response corresponds to a button press on the same or different side from stimulus presentation. An increase in response time for trials on which the colour of the stimulus corresponds to a response that is incompatible with the position of the stimulus (i.e., incongruent trials) is known as the Simon effect. A smaller Simon effect for bilinguals relative to monolinguals has been found in children (Martin-Rhee & Bialystok, 2008), young adults (Bialystok, 2006), and older adults (Bialystok et al., 2004). These findings have been taken as evidence for an advantage in bilinguals; however, it may be that bilinguals show a general processing advantage relative to monolinguals and not necessarily a specific advantage on interference suppression (see Hilchey & Klein, 2011).

More relevant to the present investigation, the bilingual advantage has also been demonstrated in older adults using the Stroop task. Zied et al. (2004) examined age and bilingualism using a Stroop task, which included versions in each of the bilingual participants' languages, as well as a between-language condition where stimuli were presented in one language, and responses were made in the other language. Participants included bilingual individuals who were either equally proficient in their two languages (i.e., balanced bilinguals) or dominant in one language over the other. The important finding from their study is that both the young and older balanced bilinguals demonstrated faster response times for all Stroop conditions than did the bilinguals with a dominant language. In terms of interference, Zied et al. focused on within- and between-language interference and found that older adults with a dominant language showed the greatest interference in between-language conditions. Although it was not reported, presumably there were no differences between the young and older balanced bilinguals. These results were taken as evidence that the manipulation of two languages by balanced bilinguals enhances inhibitory control mechanisms.

Bialystok et al. (2008) have also found that Stroop interference (defined here as the difference between congruent and incongruent colour naming) was greater for older and for monolingual participants; however, there was no interaction between these two factors. When their data were examined in terms of facilitation for congruent colour naming (i.e., the difference between neutral and congruent colour naming) and costs for incongruent colour naming (i.e., the difference between neutral and incongruent colour naming), an advantage for bilinguals relative to monolinguals became evident. That is, both older and younger bilinguals showed smaller costs relative to their monolingual counterparts.

Attentional mechanisms have also been found to be more efficient in bilingual than in monolingual young adults using the attentional network test (Costa et al., 2009; Costa et al., 2008), which is supposed to measure three attentional networks including switching, orienting, and executive attention. Specifically, Costa et al. (2008) found that bilinguals performed the task overall faster than monolinguals and demonstrated greater efficiency in the alerting and executive control networks. However, Costa et al. (2009) found that the faster response times for both congruent and incongruent trials only emerged when monitoring demands were high, suggesting that the source of the overall response time advantage for bilinguals reflects more efficient conflict monitoring relative to monolinguals. Finally, Bialystok et al. (2006) have found that bilingual older adults outperformed their monolingual peers on a task described as a modified antisaccade task, although it required manual responses (Bialystok et al., 2006). The antisaccade task requires participants to look in the opposite direction to a cue on critical trials, which requires inhibition of the prepotent response of looking in the direction of the cue. In the modified antisaccade task used by Bialystok et al., participants were required to make a manual response on the opposite side of a target to indicate an antisaccade. The superior performance of older bilinguals has been taken as further support for a protective role of bilingualism against age-related decline in executive function; however, the effect of bilingualism only emerged when manual responses were required. Bialystok et al. suggest that this is due to the relative automaticity of button press responses and saccadic eye movements. Specifically, saccadic eye movements are more automatic and less susceptible to higher order cognitive control than are manual responses, which are influenced by stimulus–response relations.

Based on this review, it seems clear that bilingualism influences executive control processes and that this persists over the course of the lifespan. The goal of the present investigation was to replicate previous findings of a bilingual advantage using a modified version of the classic Stroop task (Stroop, 1935). The sample included here was composed of a group of English monolinguals and English/French bilinguals who were native to North America, which contrasts with the bilingual samples included in previous studies. That is, most previous studies reporting an advantage for bilinguals relative to monolinguals have used samples composed predominantly of immigrants whose native language was not always English, or bilingual participants who vary with respect to their second language (L2; e.g., Bialystok, 2006; Bialystok et al., 2008; Bialystok et al., 2006; Martin-Rhee & Bialystok, 2008). Others have included only bilingual participants varying in their level of proficiency in their L2, but no monolingual comparison group (Zied et al., 2004). Thus, it is important to demonstrate whether the bilingual advantage holds in a less variable sample comparing monolingual and bilingual young and older adults. It was hypothesized that if there is in fact an advantage for bilinguals relative to monolinguals then Stroop interference would be larger in the monolinguals than in the bilinguals. Furthermore, it was predicted that the difference in performance between monolinguals and bilinguals would be greater in the older adults, demonstrating a positive effect of bilingualism on interference suppression/ inhibitory control in ageing. These findings would be consistent with the research reviewed here. Failure to support our hypotheses would raise questions regarding the robustness of the bilingual advantage.

Method

Participants

The participants for this investigation comprised individuals who had participated in studies investigating ageing and/or bilingualism in the Cognitive Psychophysiology Laboratory. Participants were included in the present investigation if they met specific language criteria. The sample consisted of monolingual and English/French bilingual young and older adults. Young participants were recruited from Concordia University and McGill University, and older participants were recruited from a database within the Cognitive Psychophysiology Laboratory at Concordia University. All participants were pre-screened using a self-report health and language questionnaire. Bilingual participants were native English speakers highly proficient in French, or who self-reported that both English and French were learned simultaneously from birth. Ethical approval for this study was obtained from the Concordia University Human Research Ethics Committee.

Table 1 provides demographic information for each participant group. The group of young adults comprised 38 monolinguals (19 males) between the ages of 18 and 35 years ($M = 22.5$, $SD = 4.5$) and 35 bilinguals (11 males) also between the ages of 18 and 35 years ($M = 23.7$, $SD = 4.0$). The group of older participants comprised 25 monolinguals (6 males) between the ages of 60 and 81 years ($M = 68.9$, $SD = 6.5$) and 20 bilinguals (7 males) between the ages of 62 and 84 years ($M = 71.9$, $SD = 5.9$).[1] Forty-seven bilingual participants reported having English as their native language and had learned French before the age of 8. Eight bilingual participants (4 young and 4 older) reported that they had simultaneously learned English and French and had no preference for one language over the other. All bilingual participants reported using both languages on a daily basis. The bilingual participants were also asked to rate their level of proficiency for listening, reading, and speaking in each language on a scale of 1–5, where 1 indicated "no ability at all", and 5 indicated "native-like ability"; the overall means for each group are reported in Table 1. Language proficiency was additionally assessed using an animacy judgement task (Segalowitz & Frenkiel-Fishman, 2005) described below. Participants were matched on age within each age group, and all demonstrated normal cognitive functioning based on the Montreal Cognitive Assessment (MoCA; Nasreddine et al., 2005). The older bilinguals had more years of education than the older monolinguals, which we controlled for statistically in our data analyses.

Materials and apparatus

Participants included in this investigation completed the MoCA (Nasreddine et al., 2005), as a measure of overall cognitive functioning; an animacy judgement task (Segalowitz & Frenkiel-Fishman, 2005), to assess relative native (L1) and second (L2) language proficiency; and a modified version of the classic Stroop task (Stroop, 1935).

MoCA. The MoCA (Nasreddine et al., 2005) is a 10-minute cognitive screening tool used to detect mild cognitive impairment in older adults. It assesses visuospatial ability, executive control, memory, attention, language, and orientation. The MoCA was included to ensure that all participants demonstrated normal cognitive function. The MoCA is scored out of 30, with a score of 26 or higher indicating normal cognitive functioning.[2]

Animacy judgement task. This task required that bilingual participants categorize, as quickly and accurately as possible, whether a noun referred to a living or nonliving object (Segalowitz & Frenkiel-Fishman, 2005). Scores on this task provided an objective measure of language proficiency. As used here, the task consisted of 72 nouns each in English and French presented in separate language blocks. Within each language block there were 64 to-be-judged nouns preceded by eight practice trials. The stimuli were presented in yellow 20-point Arial font on a black background.

[1]Given the difficulty recruiting participants who met our strict language criteria, all the groups were not matched with respect to gender. Evidence for gender differences in Stroop performance is inconsistent (see Macleod, 1991; but see Baroun & Alansari, 2006). For this reason, we compared males and females on the three conditions of the Stroop task for each age and language group. The only significant gender difference that was found was in the older bilinguals; females performed faster than males overall. Given that the speed advantage was a general one, and we were interested in Stroop interference, this was not considered further.

[2] In total, 12 older adults (5 older monolinguals and 7 older bilinguals) with scores between 23 and 25 were included in the study. Although these older adults scored below the cut-off for normal cognitive functioning, interaction with the experimenter and performance on other cognitive tasks provided no indication of impaired cognitive function. Critically, an independent-samples t test indicated no difference in MoCA scores between the two language groups ($p = .68$).

Table 1. *Demographic information for participant groups*

	Young monolinguals (n = 38) M (SD)	*Young bilinguals* (n = 35) M (SD)	*Older monolinguals* (n = 25) M (SD)	*Older bilinguals* (n = 20) M (SD)
Age (in years)	22.5 (4.5)	23.7 (4.0)	68.9 (6.5)	71.9 (5.9)
Education (in years)	15.1 (1.7)	15.5 (1.3)	13.9 (2.0)	15.9 (2.8)
MoCA	28.6 (1.3)	27.8 (1.7)	26.8 (2.0)	26.6 (2.0)
L1 self-reported language proficiency	5.0 (0.0)	4.9 (0.3)	5.0 (0.0)	4.9 (0.2)
L2 self-reported language proficiency	n/a	4.2 (0.6)	n/a	4.6 (0.6)
Coefficient of variability L1	n/a	.24 (.09)	n/a	.23 (.11)
Coefficient of variability L2	n/a	.26 (.09)	n/a	.22 (.07)

Note: MoCA = Montreal Cognitive Assessment. L1 = first language. L2 = second language.

Participants used a left key on the keyboard, to categorize the noun as animate, and a right key to categorize the noun as inanimate. Each language block contained different nouns, and there were no translation equivalents; furthermore, the blocks were matched in terms of the number of animate and inanimate judgements as well as the number of same/different responses relative to the previous trial. For the majority of participants, stimuli were presented using Inquisit Version 2.0 (Millisecond Software, Seattle, WA) on a Dell Inspiron 1521 laptop with an AMD Turion processor and Windows Vista operating system at the centre of a 15.4-inch screen.

Stroop task. A variation of the classic Stroop task (Stroop, 1935) was used to measure interference suppression/inhibitory function and was the primary focus of the present investigation. The task included three blocks of 52 trials each, there was a 150-ms posttrial pause following each trial, and a stimulus remained on the screen until the participant responded. Response time (RT) was recorded at the onset of the vocal response using a headset microphone. Response latencies were obtained for each individual trial. Participants performed both the Stroop and animacy judgement tasks using the same computer and software. In the first block, participants were presented with the words "red", "green", "yellow", and "blue" in white 20-point Arial font on a black background and were asked to read the word aloud as quickly and accurately as possible (i.e., the word reading condition). The second block consisted of circles measuring 50 pixels high and 50 pixels wide, which were coloured red (RGB: 255, 0, 0), green (RGB: 0, 128, 0), yellow (RGB: 255, 255, 0), or blue (RGB: 0, 0, 255), and participants were asked to name the colour of the circle as quickly and accurately as possible (i.e., the colour naming condition). The final block was composed of the words "red", "green", "yellow", and "blue" printed in 20-point Arial font in one of the three colours other than the colour that the word represented, and participants were asked to name the colour of the print as quickly and accurately as possible and to avoid reading the word (i.e., the incongruent colour naming condition). Each block was preceded by a series of practice trials to ensure that participants were comfortable with the stimuli and able to correctly perform the task specific to the block. Participants completed the word reading condition first, followed by the colour naming condition, and the incongruent colour naming condition was completed last.

Procedure

Participants were seated in a comfortable chair, and informed consent was obtained at the beginning of the testing session. The time to complete the tasks included here was approximately 30 minutes. Participants were compensated at the end of the testing session; young adults in the psychology program at Concordia University were compensated in the form of course credit, and all other participants were compensated 10 CAD per hour of participation.

Results

Statistical analyses were conducted using the statistical software package SPSS Version 11.5 (SPSS Inc., Chicago, IL, USA). Reported effects were significant at an alpha level of .05 (unless otherwise specified), and any significant interactions were decomposed with Bonferroni corrected simple effects analyses. Given the significant difference between monolingual and bilingual older adults in years of education, this factor was included as a covariate for all analyses of variance.

Animacy judgement task

Due to a technical error, the data for one older bilingual were not available. The coefficient of variability (CV; a measure of cognitive efficiency based on intraindividual differences in RT variability; see Segalowitz & Segalowitz, 1993) was calculated for each participant by dividing the standard deviation (*SD*) of each participant's RT for correct trials by his or her mean RT for correct trials. Trials for which the RT was less than 200 ms or greater than three standard deviations of the mean were excluded separately for each language prior to calculating the CV. The Pearson correlation between the CV in L1 and L2 was examined in order to assess relative proficiency in French and English for the bilingual participants. There was a significant correlation for both the young ($r = .87$, $p < .001$) and the older ($r = .87$, $p < .001$) bilinguals, demonstrating high relative L2 proficiency in both groups.

Stroop task

Both accuracy and RT were examined. A mixed analysis of variance (ANOVA), including the between-subjects variables age (young vs. older) and language group (monolingual vs. bilingual) and the within-subjects variable condition (word reading, colour naming, and incongruent colour naming), was conducted with accuracy as the dependent variable; see Figure 1a. There was a trend toward a main effect of condition, $F(2, 226) = 2.77$, $MSE = 14.97$, $p = .07$, demonstrating more accurate responses for both the word reading and colour naming conditions than for the incongruent colour naming condition. The effects of age and language group were not significant: $F(1, 113) = 2.6$, $MSE = 43.31$, and $F(1, 113) = 0.23$, $MSE = 43.31$, respectively.

The RT data were analysed in an initial mixed ANOVA comparing the three conditions (word reading, colour naming, and incongruent colour naming), including the between-subjects variables age (young vs. older) and language group (monolingual vs. bilingual); these data are depicted in

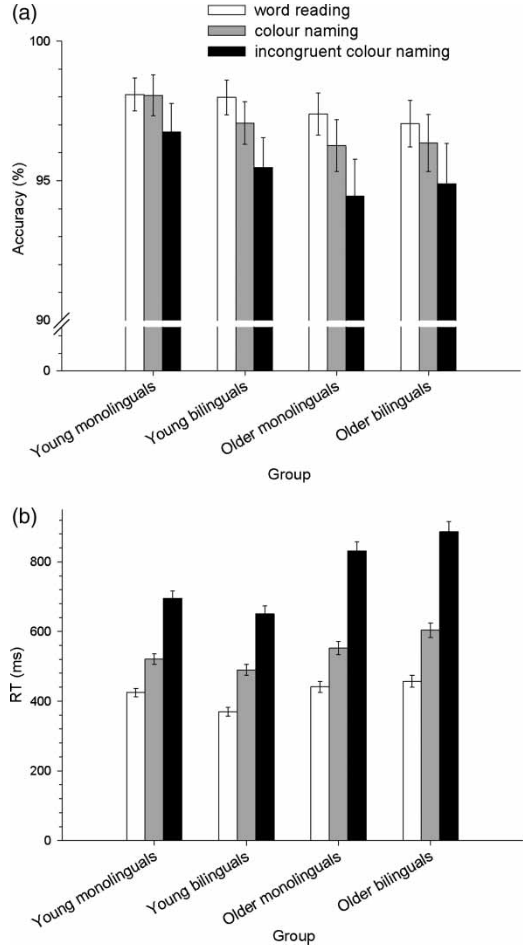

Figure 1. *(a) Mean accuracy (± SE) and (b) mean response time (RT; ± SE) for the three Stroop conditions as a function of age and language group.*

Figure 1b. There was a main effect of age, $F(1, 113) = 42.41$, $MSE = 20{,}636.38$, $p < .001$, demonstrating faster responses by the young than by older adults. An Age × Language Group interaction, $F(1, 113) = 6.83$, $MSE = 20{,}636.38$, $p = .01$, indicated that the young bilinguals were faster than the young monolinguals, whereas the two older groups demonstrated no difference in RT. There was also a main effect of Condition, $F(2, 226) = 11.47$, $MSE = 4{,}950.52$, $p < .001$, and an Age × Condition interaction, $F(2, 226) = 28.7$, $MSE = 4{,}950.52$, $p < .001$, which indicated that there was a significant difference between all three conditions in both age groups, with the fastest RTs for word reading and the longest RTs for incongruent colour naming. The source of this interaction was a larger difference in RT between young and older adults for the incongruent colour naming condition (mean difference = 185.4 ms) than for word reading (mean difference = 51.5 ms) and colour naming (mean difference = 72.5 ms), with the older adults demonstrating longer RTs. There was no significant Age × Language Group × Condition interaction, $F(2, 226) = 0.28$, $MSE = 4{,}950.52$), as would be expected if the bilinguals were demonstrating an advantage relative to monolinguals.

Following analysis of the raw data for the different conditions in the Stroop task, we further examined the effect of age and language group on Stroop interference in a between-subjects multivariate analysis of variance (MANOVA). These additional analyses were performed in order to more closely replicate the analyses in previous investigations that have found evidence for a bilingual advantage (e.g., Bialystok et al., 2008). We included several dependent variables to ensure that any effect of language group would be detected; furthermore, given that there were two baseline conditions (i.e., word reading and colour naming), the data were examined relative to both of these baselines and relative to the mean of the two. Specifically, there were six dependent variables included in the MANOVA. Three of the dependent variables were based on the raw RT data (i.e., the difference between the incongruent colour naming and colour naming, the difference between incongruent colour naming and word reading, and the difference between incongruent colour naming and the mean of colour naming and word reading). The three remaining dependent variables were based on proportional increases in RT between neutral and incongruent conditions, which were calculated by dividing the difference in RT (i.e., the three dependent variables previously described) by the RT for the corresponding neutral condition. The MANOVA revealed a main effect of age for all the dependent variables, demonstrating a smaller Stroop effect in the young adults than in the older adults (see Figure 2). Table 2 provides the relevant statistics for this analysis. There was no effect of language group or Age × Language Group interaction (all Fs < 1.7, all $p > .20$), demonstrating no advantage for bilinguals relative to monolinguals.

Discussion

The goal of the present investigation was to replicate previous findings of a bilingual advantage for executive control processes in a sample that was matched on sociocultural variables. Specifically, a modified version of the Stroop task was used to investigate interference suppression in nonimmigrant young and older bilingual and monolingual participants. The most important contribution of this study is the use of a less variable sample relative to previous investigations in which native/second language and/or immigrant status have not been controlled (Bialystok et al., 2008), or that have not included a monolingual comparison group (Zied et al., 2004). In the present investigation, all bilingual participants were native English speakers with French as their L2; they were all born in North America and were living in the Montreal area. Thus, the present study is the first to compare a nonimmigrant group of younger and older monolinguals and bilinguals using a Stroop task, thus illuminating any potential confounds due to differences in immigration.

The only advantage for bilinguals that was apparent in the present data was in the young group. Specifically, analysis of the raw RT for the three conditions of the Stroop task indicated that the young bilinguals were faster than the young

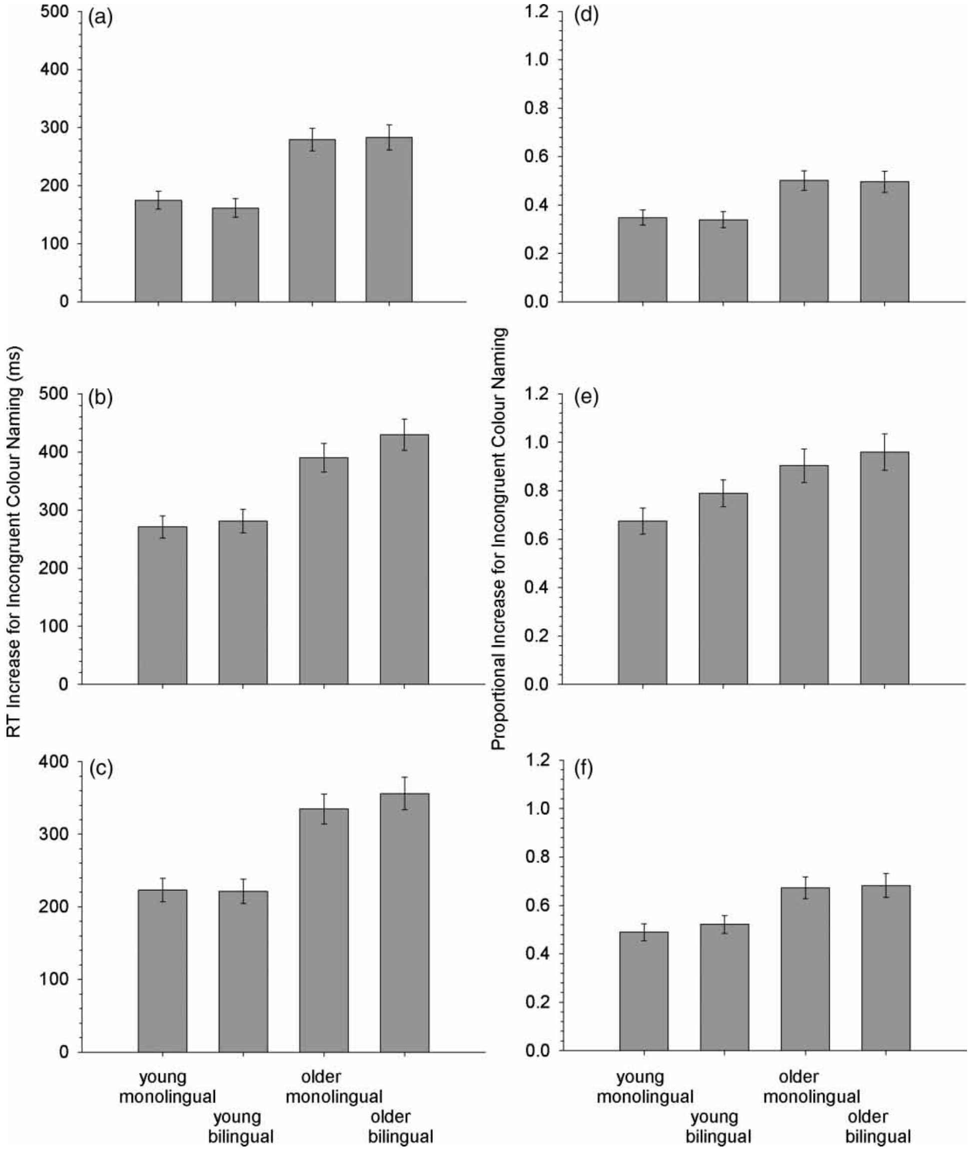

Figure 2. *The left panel shows the RT increase (*$\pm$ SE*), and the right panel shows the proportional increase (*$\pm$ SE*) for incongruent relative to neutral conditions. (a) Incongruent colour naming – colour naming; (b) incongruent colour naming – word reading; (c) incongruent colour naming – mean of incongruent colour naming and word reading; (d) (incongruent colour naming – colour naming)/colour naming; (e) (incongruent colour naming – word reading)/word reading; (f) (incongruent colour naming – mean of colour naming and word reading)/ mean of colour naming and word reading.*

monolinguals overall. This difference did not interact with condition, indicating that the bilinguals were faster across all conditions. Thus, there was no evidence for a specific advantage with respect to interference suppression. This finding is consistent with previous findings demonstrating an overall speed advantage for bilinguals relative to monolinguals in children (Martin-Rhee & Bialystok, 2008), as well as in young and older adults (Bialystok et al., 2004; Costa et al., 2009;

Table 2. *Summary of the main effect of age revealed by MANOVA for each dependent variable*

Dependent variable	F	df	MSE
Incongruent colour naming – colour naming	38.9**	1, 113	8,993.4
Incongruent colour naming – word reading	35.0**	1, 113	14,052.3
Incongruent colour naming – mean of colour naming and word reading	42.3**	1, 113	9,858.5
(Incongruent colour naming – colour naming)/colour naming	17.5**	1, 113	0.04
(Incongruent colour naming – word reading)/word reading	9.9**	1, 113	0.11
(Incongruent colour naming – mean of colour naming and word reading)/mean of colour naming and word reading	17.6**	1, 113	0.05

Note: MANOVA = multivariate analysis of variance.
**$p < .01$.

Zied et al., 2004). Given that we matched our samples on sociocultural variables, the data from the current investigation suggest that previous findings of a bilingual advantage for interference suppression may not be an effect of bilingualism per se, but may be influenced by other factors such as immigration status.

It is possible that the observation of a specific bilingual advantage is dependent on task characteristics. Using the Simon task, Bialystok et al. (2004) tested younger and older monolinguals and bilinguals and found a general speed advantage for bilinguals relative to monolinguals (i.e., faster RTs for both congruent and incongruent conditions) and a smaller Simon effect. Furthermore, the age-related increase in the Simon effect was smaller for the bilinguals than for the monolinguals, demonstrating attenuation of an age-related increase in the Simon effect for bilinguals. The present data do not show any differences in Stroop interference as a function of language group for either the young or the older age groups.

Costa et al. (2009) have argued that a speed advantage for both congruent and incongruent trials in bilinguals relative to monolinguals reveals superior conflict monitoring in bilinguals. Specifically, using a flanker task, Costa et al. showed that monolinguals and bilinguals performed similarly when 92% of trials were congruent or incongruent, and thus conflict monitoring demands were low; however, when conflict monitoring demands were higher (i.e., 50% or 75% congruent trials), a general speed advantage for bilinguals relative to monolinguals emerged for both congruent and incongruent trials when these trials were intermixed. In contrast, our stimuli were presented in blocks, and a speed advantage was demonstrated even on neutral trials when there was no need to recruit conflict monitoring processes. Our block design is comparable to Costa et al.'s low-monitoring condition (except that in our case, 100% of trials were neutral or incongruent), for which Costa et al. found no speed advantage for bilinguals. Thus, these data do not argue for a specific conflict monitoring advantage for bilinguals.

In addition to examining the raw RT, we investigated potential differences in Stroop interference. That is, we specifically compared the increase in RT from neutral to incongruent conditions. Given that there were two neutral conditions (word reading and colour naming) in the present version of the Stroop task, we examined the increase in RT relative to both neutral conditions, as well as the average of the two. Furthermore, we included proportional increases in RT in order to control for any general effects of age-related slowing. By including all six of these dependent variables, we are confident that the data have been thoroughly examined and that any advantage for bilinguals relative to monolinguals would manifest itself in the results. However, the only significant finding, apart from the general speed advantage described above, was that older adults consistently demonstrated greater Stroop interference than young adults. There was no effect of being bilingual on Stroop interference. This does not replicate previous findings (Bialystok et al., 2008); however, it is noteworthy that the advantage in the Stroop task found by Bialystok et al. was not apparent in an analysis of the raw

RTs. Specifically, the advantage emerged when Stroop interference was defined as the difference between congruent colour naming (where there is a facilitation effect) and incongruent colour naming, which conflates a possible facilitation effect and a possible interference effect. In the present investigation, there was no congruent colour naming condition; therefore, it was not possible to examine facilitation in our sample. Instead, our cost analyses are relative to a neutral condition, which is a purer assessment of an interference effect. Bialystok et al. also examined the percentage increase in RT for incongruent colour naming relative to neutral colour naming, which was similar to our analysis of proportional increases in RT. Bialystok et al. reported smaller costs for bilinguals than for monolinguals, a result that was not replicated in the present investigation.

The data reported here are inconsistent with previous findings, suggesting that the bilingual advantage may not be as robust as the literature suggests. Specifically, we do not find an advantage for bilinguals relative to monolinguals in either age group when the groups are matched on sociocultural variables. There are several alternative explanations for our failure to replicate previous findings, each of which are discussed in turn.

The sample included here comprised an older group of 25 monolinguals and 20 bilinguals and a younger group of 38 monolinguals and 35 bilinguals. Although this is not a large sample, it is comparable to previous studies that have found a bilingual advantage on the Simon task (15 older adults in each language group; Bialystok et al., 2004) and on the Stroop task (24 participants in each group; Bialystok et al., 2008). Thus, it seems likely that if there was in fact an advantage for bilinguals, our sample size would provide adequate power to detect it.

Another possibility is the number of years of education. As can be seen in Table 1, the older adults in our sample had higher than average levels of education;[3] furthermore, within the older group the bilinguals had significantly more years of education than their monolingual peers. This could result in a bias towards observing an advantage for the older bilinguals, which we did not observe. On the other hand, it is possible that such a highly educated sample might not show an additional benefit of bilingualism. However, the level of education in our sample of older adults was comparable to that in other studies that do find an advantage for older bilinguals relative to monolinguals (Bialystok et al., 2008; Bialystok et al., 2006). Despite this, a question that arises is whether a bilingual advantage would be present, or even larger in a sample of older adults with average and/or below-average education.

In a related manner, all our participants were high functioning, including the older participants who were willing and able to travel to the lab for research participation. Participants were also screened to be in good health. This may have biased our sample, resulting in such a high-functioning group that differences between monolinguals and bilinguals were not detectable. However, bilingualism is hypothesized to provide protection against age-related declines in executive function that are associated with normal, healthy ageing. Therefore, one would expect to observe the bilingual advantage unless there was a systematic difference in cognitive functioning between the monolingual and bilingual groups. A comparison of the MoCA scores for the monolingual and bilingual older adults revealed no difference in global cognitive functioning between the two groups, thus reducing this possibility as an alternative explanation.

Another possibility is that the bilingual advantage emerges only under demanding circumstances (e.g., Bialystok et al., 2006; Costa et al., 2009). For instance, Costa et al. only found an advantage for bilinguals when congruent and incongruent trials were intermixed with at least 25% incongruent trials. In the task used in the current investigation, the trial types were blocked, and thus the monitoring demands were low. Despite this we did find a general speed advantage for young bilinguals.

It has been demonstrated that the magnitude of the Stroop interference effect can be modulated by

[3] The Public Health Agency of Canada (2002) reported that in 1996, 60% of Canadian seniors never completed high school (i.e., corresponding to 11 years of education in our measurement), with one third having no secondary education.

the proportion of incongruent trials within a block (e.g., Kane & Engle, 2003; Long & Prat, 2002; Tzelgov, Henik, & Berger, 1992). Thus, it is possible that the blocked design used in the current investigation was not sensitive enough to detect a bilingual advantage. However, previous investigations that have found an advantage for older bilinguals using the Stroop task have also used a blocked design (Bialystok et al., 2008; Zied et al., 2004). Therefore, we do not believe that our failure to replicate previous findings is due to the task design; instead, it probably reflects variability in the robustness of the effect. The exact reasons for this variability are unknown, but may be due to differences in participant samples, such as differences in the use of immigrant and nonimmigrant samples. These differing groups of bilinguals are likely to differ on important variables concerning language use, such as age of acquisition, proficiency, and the contextual, social, and instrumental use of one's two languages. These variables could possibly vary with respect to their impact on executive function demands when managing multiple languages.

In the present investigation, all of the bilingual participants either were native English speakers with French as their second language or reported no nominal L1 and had learned both French and English simultaneously from birth. In contrast, in Bialystok et al. (2008) the majority of older participants were immigrants (20 of 24 participants), and English was more likely their L2, with differing L1s. Other research has suggested that immigrant status may be important. Specifically, Chertkow et al. (2010) found a protective effect of speaking two or more languages against a diagnosis of Alzheimer's disease in a sample of immigrants and a trend towards a similar finding in nonimmigrants whose native language was French, but no such effect in nonimmigrant bilinguals whose native language was English (although see Craik, Bialystok, & Freedman, 2010). Chertkow et al. argued that immigrants differ from nonimmigrants in many ways (e.g., diet, stress, life history) that are not typically measured. These, plus the other differences in second language use outlined above, may prove to be important variables to explore. As we demonstrated in the present investigation, when immigrant status is controlled, an advantage for bilinguals relative to monolinguals on a Stroop task is elusive.

An interesting avenue for future research is to examine the bilingual advantage using neuroimaging techniques. This would allow for the investigation of more subtle differences between monolinguals and bilinguals that may not be apparent in purely behavioural measures. For example, using magnetoencephalography, Bialystok et al. (2005) found differences between monolingual and bilingual young adults in terms of the regions of brain activity associated with performance of a Simon task in the absence of RT differences. Interestingly, research in our lab using event-related brain potentials recorded during three different attention control tasks has revealed differences between young bilinguals and monolinguals in terms of their neural responses but not in their behavioural responses (Kousaie & Phillips, 2011b). Thus, it might be more parsimonious to talk about differences between groups as a function of language status, rather than advantages *per se*.

In sum, the present investigation does not replicate previous studies demonstrating an advantage associated with being bilingual. Given our care in controlling for sociocultural factors, the current findings raise questions with respect to the robustness or specificity of a bilingual advantage and its role as a buffer against age-related declines in executive function. Future studies should take advantage of more sensitive neuroimaging techniques to further investigate whether there is an advantage too subtle to be detected behaviourally. We also believe that differences between immigrant and nonimmigrant bilingual samples in second-language characteristics may contribute to variability in the effect.

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