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# L2 proficiency predicts inhibitory ability in L1-dominant speakers

## Abstract

- Aims and Objectives

Bilinguals reportedly perform better in tasks that require the suppression of interference because of the constant practice in linguistic inhibition. However, previous literature was largely based on comparisons of pure monolinguals and balanced bilinguals. Those in between the two extremes were rarely examined. This project aimed at studying whether the population who primarily speak in first language (L1) with different level of second language (L2) proficiency also enjoy bilingual advantage.

- Methodology

Twelve monolingual and thirty-eight bilingual Hong Kong older adults were recruited to perform the Stroop task and the L2 (English) proficiency tests. The subjects were all frequent L1 (Cantonese) speakers with various levels of L2 proficiency.

- Data and Analysis

Pearson correlation and multiple regression analyses were used to identify the relationship between inhibition ability (Stroop score) and demographic and language background variables (including proficiency in and frequency of exposure to their L2).

- Findings

Both correlation and multiple regression analysis showed that the subjects with higher proficiency in L2 performed significantly better in the Stroop task. The results suggested that higher L2 proficiency leads to higher difficulty in suppressing it, thus the training of inhibition is more effective.

- Originality

This study expanded the literature on bilingual advantage from a dichotomous comparison between monolingual and bilingual to the more continuous spectrum of bilinguals with different levels of L2 proficiency. This study aimed at showing a fuller picture of bilingualism in the world.

- Significance/Implications

This study proposed that with high proficiency in L2, frequent L1 speakers could also enjoy cognitive advantages brought by bilingualism. Our study provides further evidence to the bilingual advantage hypothesis.

## Introduction

### ***Age-related cognitive decline***

Age is negatively associated with a number of cognitive abilities (Park & Reuter-Lorenz, 2009; Rey-Mermet & Gade, 2018). For instance, the Stroop effect was greater in older adults than in younger adults (West & Alain, 2000), and older adults responded to incongruent trials 50% slower than younger adults in the flanker task (Zhu, Zacks, & Slade, 2010). It is believed that age-related decline in inhibitory ability leads to poorer performance in tasks that require the subjects to selectively attend to one feature of the stimulus and simultaneously ignore the interfering feature (West & Alain, 2000). On the other hand, research has found that cognitive reserve could be built up from life experience to protect people from brain pathology in normal ageing (Stern, 2012). Bilingualism is among one of the life experiences that has been proposed to have potential in sustaining cognition in old age (Antoniou, Gunasekera, & Wong, 2013).

### ***The bilingual advantage debate***

Grosjean (2010) has estimated that over half of the world's population is bilingual with different levels of fluency. Apart from the ability to communicate with speakers of other languages, bilinguals were found to have better cognition compared with monolinguals. The bilingual advantage was generally found in the executive control domain, such as in the task-switching task (Prior & Gollan, 2011), Simon task (Bialystok, Craik, Klein, & Viswanathan, 2004), Stroop task (Bialystok, Craik, & Luk, 2008), Sustained Attention to Response Task (Bialystok et al., 2008), and Attention Network Task (Pelham & Abrams, 2014). These tasks varied in terms of stimuli and procedures, but all required the subjects to attend to a certain feature of the stimulus, and ignore the interfering ones. In some studies, the bilingual advantage could transfer to other cognitive domains, including episodic memory (Schroeder & Marian, 2012) and working memory (Bialystok, Poarch, Luo, & Craik, 2014). The effect was not limited to younger adults, but also found in infants (Singh et al., 2015), toddlers (Crivello et al., 2016), and older adults (Bialystok et al., 2008; Bialystok, Craik, & Freedman, 2007; Bialystok et al., 2014). It seems that such an advantage is most robust in bilingual older adults instead of younger bilinguals, suggesting that bilingualism may provide a buffer against age-related cognitive decline (Antoniou, 2019). Bilingual older adults were found to score higher than their monolingual counterparts in the Mini Mental State Examination (MMSE) – a simple test that examines various cognitive domains (Padilla, Mendez, Jimenez, & Teng, 2016). In addition to having better cognitive abilities, bilinguals were found to show Alzheimer's Disease symptoms 4.1 years later than the monolinguals (Bialystok et al., 2007).

The Inhibitory Control Model (Green, 1998) might explain the cognitive advantages of bilingualism (Pelham & Abrams, 2014; Prior & MacWhinney, 2010; Verreyt, Woumans, Vandelanotte, Szmalec, & Duyck, 2015). According to this model, whenever bilinguals attempt to produce a word, both languages are activated simultaneously. Lexico-semantic competition occurs to produce the word in the target language. Only when the unwanted language is successfully inhibited could a bilingual output the word in the target language. The lexico-semantic competition is affected by several factors, such as the cognitive processes, linguistic contexts (Green & Abutalebi, 2013), proficiency and frequency of exposure to languages (Perani et al., 2003). The linguistic inhibition was proposed to be at least partially overlapping with domain-general inhibition (Abutalebi & Green, 2007), hence bilinguals could perform better in tasks that require inhibition.

The bilingual advantage on cognitive abilities was not consistently reported (for review, see Antoniou, 2019). For instance, Kirk, Fiala, Scott-Brown, and Kempe (2014) could not find any significant difference between the monolingual and bilingual group in the Simon task. The effect was also not found in other studies using executive tasks, for instance, the Stroop task (Kousaie & Phillips, 2012) and Sustained Attention to Response Task (Kousaie, Sheppard, Lemieux, Monetta, & Taler, 2014). As pointed out by Antoniou and Wright (2017) and emphasized again by Antoniou (2019), some research groups consistently found evidence supporting bilingual advantage, while others never seemed able to find such a pattern. Their implication directs toward a critical question in studies of the bilingual advantage: whether the "bilingual advantage" is a universal phenomenon or is subject to special characteristics of certain bilingual groups.

### *The dichotomous comparison in the literature*

The direct way to investigate bilingual advantage would be comparing bilinguals and monolinguals. It was probably the most commonly adopted methodology from early studies (e.g. Bialystok, 1988; Bialystok et al., 2008; Bialystok et al., 2007; Costa, Hernandez, & Sebastian-Galles, 2008) to recent articles (e.g. Padilla et al., 2016; Warmington, Kandru-Pothineni, & Hitch, 2019) on bilingual advantage. Yet, there were many individual variations that might affect the bilingual advantages on cognition, for instance their education, immigration status, and social economic status (van den Noort, Struys, & Bosch, 2019). The differences between the two language groups might affect the interpretation of the comparison. For instance, in Hong Kong, the language of instruction used in many secondary schools and at tertiary level is English, which is the L2 for the majority of locals. Therefore, nobody with higher education would be a monolingual. With higher education, it is natural that they would have very different career paths compared with those who only finished primary school. In this case, the monolinguals and bilinguals might have significantly different life experience, and life experience was believed to be affecting cognition in old age (Stern, 2012).

In previous literature, it was common that the bilinguals recruited were "balanced bilinguals", which referred to people having similar proficiency and frequency of use of both languages. However, it should be noted that even for those balanced bilinguals, the two languages do not have equal strength and one of them would be the dominant language. Therefore, the effort required for inhibiting the language is different. In a language-switching naming task, Meuter and Allport (1999) found that switching from the weaker language to the more dominant language required a longer reaction time compared with the opposite direction. It was suggested that the asymmetric cost is brought by different strengths of bilinguals' two languages. Because the dominant language is stronger, it is more difficult to suppress.

Once the dominant language is suppressed, however, it is more difficult to release it from suppression, which resulted in a slower switching time from the less dominant to the dominant language. Goral, Campanelli, and Spiro (2015) recruited 106 Spanish–English bilinguals of different degrees of proficiency and frequency of use, and found that less balanced bilinguals showed a smaller Simon effect. Their findings suggested that suppressing the more dominant language is more effortful for people who had a less fluent L2. Unbalanced bilinguals therefore need more effort in suppression, which is more cognitively beneficial. Linck, Hoshino, and Kroll (2008) supported this claim and found that more proficient language learners showed worse inhibitory control compared with the less proficient learners. In contrast, Yow and Li (2015) found that more balanced English–Mandarin bilinguals performed better in the Stroop task in a group of Singaporean young adults. Boumeester, Michel, and Fyndanis (2019)'s regression analysis also supported the notion that the more proficient bilinguals are in their L2, the better inhibition they have.

***Moving beyond***

Bilingualism is a life long experience. It is inevitable that subjects with strictly matched backgrounds would still show individual differences in their language experience (Laine & Lehtonen, 2018). Placing a bilingual population and its monolingual counterparts at the ends of a continuum essentially ignores those who are in between. Studies in bilingualism should move beyond dichotomously classifying subjects into monolinguals or bilinguals (Takahesu Tabori, Mech, & Atagi, 2018), and treat bilingualism as a spectrum of different aspects of language experience (DeLuca, 2019; DeLuca, Rothman, Bialystok, & Pliatsikas, 2019).

People use their L2 in various ways and to various degrees. Therefore, it is impossible, if not inappropriate, to generalize an observation in one scenario to the diverse bilingualism. For example, in multi-ethnicity countries such as India, people had to switch between languages depending on the interlocutors (Mishra, 2018). There are people whose L2 is used exclusively in formal situations (e.g. ethnic minorities in China when communicating with the central government, Wang and Phillion, 2009), and there are people who learn a foreign language just to satisfy their intellectual curiosity but not for daily communication. The different pattern of using language therefore created different cognitive demand in suppression, and thus each had different cognitive outcome (Dong & Li, 2015; Green & Abutalebi, 2013).

A few recent papers addressed the issue of studying multiple aspects of bilingualism. For instance, Pot, Keijzer, and de Bot (2018) used linear mixed effect modelling and found that the proficiency of L2 and L3, and the pattern of language use were significant predictors of cognitive abilities. Yow and Li (2015) used multiple regression modelling and found that more balanced bilinguals performed better in the Stroop task. Multiple regression analysis were used to study how language variables contributed to cognitive abilities of different domains (Boumeester et al., 2019).

These studies started to treat bilingualism as a continuous value rather than one categorical variable, and examined the relationship of language experience and cognitive abilities within bilinguals participants. The present study followed this trend and aimed at serving as the stepping-stone in the investigation of bilinguals who speak dominantly in L1 with different degrees of proficiency in L2.

### *Current study*

We investigated the relationship of bilingualism and inhibitory ability in older adults by correlating the cognitive scores with several language history variables within a group of subjects that share a similar language and social background. Hong Kong is a former British colony, so locals are exposed to English in their schools and community. However, Cantonese has remained the primary language of the locals in daily communication, while English is mostly used in business, schools and official documents. Therefore, our subjects are frequent L1 users, but could be proficient in L2 due to education or work. According to the Inhibitory Control Model's hypothesis (Green, 1998), if L2 is of high proficiency, the effort required to suppress it during L1 production would be larger than those who had lower L2 proficiency. Following Goral et al. (2015)'s interpretation, we hypothesize that the more proficient one is in L2, the more efficient is the practice of inhibition.

Given the importance of language history in the study of bilingualism, it is surprising that less than half of the studies use objective measures to assess the proficiency and frequency of use of languages (Surrain & Luk, 2017). Even though some studies showed that objective measures and subjects' self-reported proficiency were highly correlated (Luk & Bialystok, 2013), in some cultures, people tend to be either over-modest or over-confident about their language abilities. An objective measurement is needed to carefully examine subjects' language proficiency, especially when the study involves people from different cultural backgrounds (Hulstijn, 2012). Older Chinese adults tend to rate their ability into lower ranking than they truly are, to avoid being considered as immodest or even arrogant. To avoid inaccurate self-assessment, we administered two standard English proficiency tests to accurately and objectively measure the language ability of the subjects.

This study intended to explore the correlation of language experience and the inhibition ability of bilinguals who speak in their L1 much more often than L2.

## Methods

### *Participants*

Sixty-one Hong Kong older adults were recruited in this study. Subjects were screened using the Montreal Cognitive Assessment Hong Kong version (MoCA-HK) (Wong et al., 2015). Two with poor vision, two with psychological or neurological pathology history, one illiterate, two non-Cantonese native speakers, two subjects with color vision deficiency and two patients with mild cognitive impairment (MoCA score lower than the 7th percentile of the respective age and education range) were excluded. A total of 50 subjects were included in our data analysis. A subject was defined as a monolingual if (1) he/she claimed to know no English at all, or (2) he/she claimed to know English but could not score any marks in the Shipley Vocabulary Test (Shipley, 1940).

A total of 12 monolinguals (7 males, $M_{\text{age}}$ = 67.82, *SD* = 3.86) and 38 bilinguals (15 males, $M_{\text{age}}$ = 67.03, *SD* = 4.49) were included in our analysis. All subjects spoke Cantonese as their mother tongue, and lived in Hong Kong for most of their life. All except five subjects acquired English as second language, but six of them declared they could not finish any questions in the Shipley test and were therefore classified as monolinguals. In general, bilinguals had earlier age of acquisition (AoA) of English (*M* = 7.87, *SD* = 3.46), compared with the monolinguals (*M* = 12.14, *SD* = 12.42), though the difference was only marginally significant ($F$ (1, 43) = 3.40, $p$ = .07, $\eta_p^2$ = .07). The subjects' English proficiency was measured using two tests objectively, (1) Lexical Test for Advanced Learners of English (LexTALE) (Lemhofer & Broersma, 2012) and (2) Shipley Vocabulary test (Shipley, 1940). The subjects received HKD$200 for completing the experiments. All procedures were approved by Human Subject Ethics Subcommittee of the Hong Kong Polytechnic University (Ref. No: HSEARS 20151228003-01). Written informed consent was obtained from all subjects. Table 1 shows the demographic information of the subjects.

Table 1 Demographic information of the subjects. Standard deviations are shown inside brackets. * $p < .05$, ** $p < .01$, *** $p < .001$.

| | Monolingual | | Bilingual | | Group difference between monolinguals and |
|---|---|---|---|---|---|
| | Male (*n* = 5) | Female (*n* = 7) | Male (*n* = 15) | Female (*n* = 23) | |

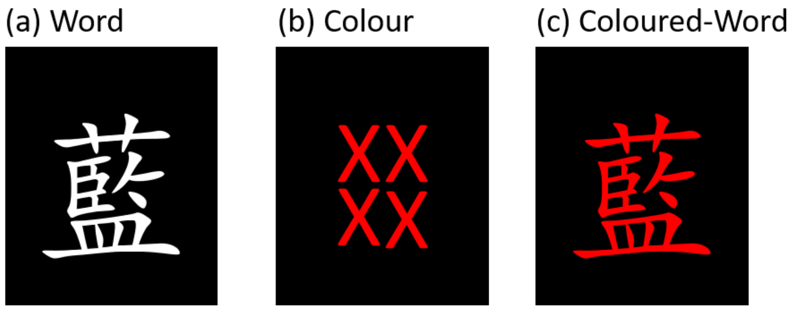
| | | | | | bilinguals (*p*) |
|---|---|---|---|---|---|
| Age | 68.04 (4.01) | 67.66 (4.06) | 68.18 (5.27) | 66.27 (3.84) | .59 |
| Education (years) | 8.80 (3.03) | 7.29 (2.14) | 15.67 (3.90) | 13.72 (4.41) | < .001*** |
| MoCA-HK | 26.80 (1.30) | 25.43 (3.31) | 27.73 (1.67) | 27.83 (1.83) | .009** |

***Tasks***

The present study is a part of a larger project. The subjects completed a set of cognitive behavioral tests that examined various cognitive domains in a 2-hour session. On the day of receiving the report of the cognitive tests, they completed the language background questionnaire and two English proficiency tests if they indicated that they speak English to any degree in the questionnaire. The test battery included the Stroop test (Golden & Freshwater, 1978; Stroop, 1935), digit span forward test (Woods et al., 2011), Hong Kong List Learning Test (Chan & Kwok, 2006), one-back, Tower of Hanoi, picture naming, verbal fluency, and Raven's Standard Progressive Matrices (Raven & Raven, 1998). Because the focus of bilingual advantage lies in inhibitory control, this paper will focus on the Stroop task. The Stroop task was the first task completed by all subjects, so the results should not be affected by other tasks.

In the Stroop task, the subjects were presented with three tables, each comprising of 6 columns of 20 stimuli. The first table (condition W) consisted of Chinese characters for the color "red", "blue", "yellow", and "green" printed in white on a black background in random order. The second table consisted of colored "X" (condition C) in the above four colors, while the third one had Chinese characters printed in a semantically incongruent color (condition CW). Figure 1 shows the examples of the stimuli of the three conditions. The subjects were instructed to name the Chinese words of the first table, and the color of the second and third tables. The subjects were given 45 seconds each to name the word or color as quickly and as accurately as possible. They were instructed to repeat the table if they could finish reading it within 45 seconds and to stop only when the time was up. Self-correction was encouraged and only wrong answers without correction were regarded as incorrect responses. The task was presented using E-Prime 2.0. Subject's speech responses were recorded also with E-Prime 2.0.

Figure 1 Examples of the stimulus used in Stroop task. (a) Condition W (Word), the Chinese character for "blue"; (b) Condition C (Color); (c) Condition CW (Colored-word), the word "blue" written in red.




English (L2) proficiency was measured using (1) LexTALE (Lemhofer & Broersma, 2012) and (2) Shipley Vocabulary Test (Shipley, 1940). In the LexTALE task, the subjects have to judge whether a sequence of letters was a real English word or a pseudoword. The subjects were instructed to press the right button to indicate if it was a real word, and to press the left button if they believed that it was a pseudo-word. They were reminded that they did not necessarily need to know the meaning to press the right button, as long as they believed that it was a real word. The task consisted of 60 trials and the ratio of real word to pseudo-word was 2:1. The subjects were required to answer all questions without time limit. The task was presented by E-Prime 2.0. The score of this test was calculated using the following formula provided by the original authors (Lemhofer & Broersma, 2012):

$$ACC = \left(\frac{\text{N correct real words}}{40} \times 100\right) + \left(\frac{\text{N correct pseudowords}}{20} \times 100\right) \div 2$$

In the Shipley Vocabulary task, subjects had to choose a word that has the same or the most similar meaning with the probe word out of four choices. The task consisted of 40 questions and was administered in pen-and-paper format.

A language background questionnaire was also administered. The questions included demographic information, age of acquisition, subjective rating of language ability and the frequency of using different languages in various scenarios. The subjective rating of language ability was separated into the four elements of language: listening, reading, writing and speaking on a Likert scale of 1 to 7, with 1 being "very weak" and 7 being "very strong". The mean of the four was used in the analysis in this study. Frequency was measured by Likert scales of 1 to 7, with 1 being "never" and 7 being "always".

## Results

### *Comparison of monolinguals and bilinguals*

Only 12 monolinguals were compared with 38 bilinguals of varying degree of L2 proficiency so the comparison should be interpreted with caution. As shown in Table 1, the two groups were significantly different in education years ($F$ (1,48) = 25.33, $p < .001, \eta_p^2 = .35$) and MoCA score ($F$ (1,48) = 7.37, $p = .009$, $\eta_p^2 = .13$).

In the Stroop task, the two groups did not differ in word or color naming, but were significantly different in color-word condition ($F$ (1,48) = 8.74, $p = .017$, $\eta_p^2 = .15$). Table 2 shows the Stroop test results of the two groups. The results suggested that the two groups had similar naming speed, but differed in suppressing interference.

Table 2 Results of monolinguals and bilinguals in three Stroop task conditions and interference score. Standard deviations are shown inside brackets. * $p < .05$, ** $p < .01$, *** $p < .001$.

| | Monolinguals (*n*=12) | Bilinguals (*n*=38) | Group difference (*p*) | $\eta_p^2$ |
|---|---|---|---|---|
| Stroop W | 81.42 (9.04) | 87.68 (12.88) | .125 | .05 |
| Stroop C | 54.67 (11.73) | 60.89 (11.70) | .115 | .05 |
| Stroop CW | 23.83 (7.38) | 31.24 (7.61) | .005** | .15 |

### *Language background of the bilinguals*

To study whether L2 proficiency affects inhibition ability, only those who scored more than 1 mark in the Shipley task were included in the following analysis. Our subjects showed a large variation in English proficiency. In the Shipley Vocabulary Task, the highest score obtained was 31, with an average of 16.16. For LexTALE, subjects scored between 38.75 and 92.50, with an average of 65.76. Table 3 shows the language background information of the subjects.

Because it was possible that females had less chance of education compared with males in this generation due to financial and cultural reasons, a one-way ANOVA was done to compare the two genders in demographic and language variables. No gender differences were found in any of the variables (see Table 3).

None of the language background variables were correlated with age except for AoA of English (*r* = .52, *p* = .001), suggesting language ability and usage pattern were not associated with age.

Table 3 Language background information of the bilinguals. * *p* < .05, ** *p* < .01, *** *p* < .001.

| | **Male (*n* = 15)** | | **Female (*n* = 23)** | | **Total (*n* = 38)** | | **Gender differences (*p*)** |
|---|---|---|---|---|---|---|---|
| | ***M*** | ***SD*** | ***M*** | ***SD*** | ***M*** | ***SD*** | |
| AoA of English | 5.99 | 0.97 | 7.70 | 3.57 | 7.87 | 3.46 | .708 |
| Frequency of using Cantonese (1 to 7) | 5.50 | 1.16 | 5.50 | 1.16 | 5.72 | 1.06 | .107 |
| Frequency of using English (1 to 7) | 4.27 | 1.50 | 4.13 | 1.32 | 4.18 | 1.38 | .232 |
| Shipley (max. = 40) | 19.00 | 9.34 | 14.30 | 9.37 | 16.16 | 9.52 | .139 |
| LexTALE (max. = 100) | 69.58 | 13.07 | 63.26 | 14.59 | 65.76 | 14.18 | .183 |
| Self-rated Cantonese proficiency (1 to 7) | 6.20 | 0.58 | 5.99 | 0.97 | 6.07 | 0.84 | .455 |
| Self-rated English proficiency (1 to 7) | 4.27 | 1.50 | 4.13 | 1.32 | 4.18 | 1.38 | .770 |

All subjects indicated they were more fluent in Cantonese than English, and used Cantonese more frequently than English. Similar to previous literature, the self-rating of language ability was positively correlated with both the Shipley test (*r* = .73, *p* < .001) and LexTALE (*r* = 73, *p* < .001), the two objective measurements. To ensure objectivity in this study, only the Shipley and LexTALE scores but not the self-reported proficiency would be used in the analysis.

### ***Stroop task***

Two-tailed Pearson correlation analysis was done between the CW condition of the Stroop task and both the demographic information (age, education, MoCA) and linguistic variables reported in Table 3 (Shipley, LexTALE, Self-reported proficiency of Cantonese and English, Frequency of using Cantonese and English, and AoA of

English).Significant correlations were found between Stroop CW condition and age (*r* = −.42, *p* = .008), Shipley test (*r* = .39, *p* = .016), and AoA of English (*r* = −.42, *p* = .009) only.

Because age is known to affect inhibition ability, we performed a partial correlation analysis on the three Stroop conditions and Shipley test, with age being controlled for. Stroop CW was found to be significantly correlated with Shipley score with age controlled for (*r* = .35, *p* = .032), but not in W (*r* = .26, *p* = .122) and C (*r* = .24, *p* = .157) conditions.

***Multiple Regression Model***

To understand the contribution of each variable to the results of the Stroop task, a multiple regression analysis was run. A model was constructed to predict the number of correct responses in CW condition, by entering age, gender, education, Shipley, LexTALE, AoA of English and Frequency of using English as independent variables via Automatic Linear Modelling function using SPSS version 25. The largest Cook's distance detected in our dataset was 0.25 so no outliners were eliminated from our dataset. The program then built the multiple regression model automatically using the best subset as the selection method and reported the one that had the lowest Akaike Information Criterion Corrected (AICC) value (Yang, 2013). The Shipley score and Gender remained in the final model as significant predictors ($F$ (4, 33) = 8.24, $p < .001$), with an adjusted $R^2$ of .44. Table 4 shows the final model. Participants predicted Stroop CW result is equal to 31.48 + 0.48 (Shipley) + 6.86 (Gender = Female) – 0.56 (AoA of English) – 0.53 (Education). In other words, participants produced 0.48 more responses if they scored 1 mark more in Shipley Vocabulary test, and female had 6.86 more correct responses than male. Shipley (*t* = 3.63, *p* = .001) and Gender (*t* = 3.46, *p* = .002) were both significant predictors of Stroop CW condition score, while AoA of English (*t* = .29, *p* = .061) and Education (*t* = .28, *p* = .068) reached marginal significance. A post-hoc analysis was conducted using G*Power 3.1 (Faul, Erdfelder, Buchner, & Lang, 2009) to test the power of the multiple regression analysis with an alpha of .05, and the power achieved was .99, indicating a large effect size.

Table 4 Multiple regression analysis table using best subset method to predict Stroop CW score. Variables entered were: age, gender, education, Shipley, LexTALE, AoA of English and Frequency of using English ($F$ (4, 33) = 8.24, $p$ < .001). * $p$ < .05, ** $p$ < .01, *** $p$ < .001.

| | **Beta** | **SE** | ***t*** | ***p*** |
|---|---|---|---|---|
| (Constant) | 31.48 | 4.98 | 6.32 | < .001 *** |
| Shipley | 0.48 | 0.13 | 3.63 | .001 ** |
| Gender (Female) | 6.86 | 1.98 | 3.46 | .002 ** |
| AoA of English | -0.56 | 0.29 | -1.94 | .061 |
| Education | -0.53 | 0.28 | -1.89 | .068 |

The contribution of the above factors were unique in CW condition, as they were not present in other conditions that did not require inhibitory skill. Using the same variables and procedures to predict number of responses in W and C, we found that predicted W responses = 145.05 + 0.42 (LexTALE) – 1.14 (Age), $F$ (3, 34) = 6.08, $p$ = 002, adjusted $R^2$ = .29, with LexTALE ($t$ = 2.84, $p$ = .008) and Age ($t$ = −2.81, $p$ = .008) both being significant predictors. Post-hoc analysis showed that the power achieved was .96. For predicted C responses, it was equal to 136.86 − 1.27 (Age) + 0.33 (Shipley) + 6.01 (Gender = Female), $F$ (3, 34) = 8.85, $p$ < .001, adjusted $R^2$ = .39, with age being the only significant predictor ($t$ = −3.60, $p$ = .001). Post-hoc analysis showed that the power achieved was .99, indicating a large effect size.

## Discussion

Previous literature usually regard bilingualism as a dichotomous variable, and recruited subjects who were either balanced bilingual or purely monolingual (Takahesu Tabori et al., 2018). However, many bilinguals are in the middle of the two extremes. This study aimed to be the stepping-stone in exploring those in the middle. This study recruited older adults who frequently speak in L1 (Cantonese) in daily activities, and with varying degrees of proficiency in L2 (English). The subjects performed the Stroop task, which measured their inhibition ability, together with the Shipley Vocabulary test which estimated the English vocabulary size and LexTALE that measured general English proficiency. Overall, both correlation analysis and multiple regression analysis showed that L2 proficiency is positively associated with bilingual advantage in inhibition ability.

***Second language proficiency affects inhibition***

Within the bilinguals, both correlation analysis and multiple regression model suggested that the higher the score in Shipley (i.e., higher proficiency in English), the higher the score in Stroop CW condition (i.e., better inhibition ability). Literature demonstrated that L2 is usually the weaker language of a bilingual, therefore, bilinguals would need to suppress their L1 during L2 production with greater effort (Meuter & Allport, 1999). In other words, when a bilingual is speaking in their more dominant L1, the need for suppression and the effort to do so is less than when they need to speak in L2. Because our subjects were frequent L1 speakers, the need for suppressing the stronger language is less than frequent L2 speakers. In this case, in order to practice linguistic inhibition effectively, the weaker language had to increase its strength by improving proficiency. Our result was in line with previous literature that L2 proficiency facilitated inhibitory ability in L1-dominant speakers (Boumeester et al., 2019; Xie & Pisano, 2019).

Costa and Santesteban (2004) found that the asymmetric cost in switching from the weaker language to the dominant language was only present in L2 learners, but not in a group of highly proficiency users. They suggested that after mastering the L2, the high proficiency group minimized the need for inhibiting the other language. Therefore, they do not have the so-called inhibition training effect. Previous literature proposed that highly proficient bilinguals, for example, interpreters (Woumans, Ceuleers, Van der Linden, Szmalec, & Duyck, 2015), rely on different linguistic networks when processing speech in different languages. Our results, however, found that higher proficiency in L2 facilitated inhibition ability. The difference between the literature and our study was possibly that the L2 proficiency of our subjects were not as high as that of interpreters, and therefore no independent network was developed yet for specific language processing.

It should be noted that the proficiency effect was only obtained from the Shipley Vocabulary test, but not in the LexTALE. This result was unexpected because both tests measured English proficiency. One possible explanation is that due to the design of the tests, the subjects could finish them using different strategies. For instance, Shipley is a synonym test in which the subjects could only answer questions correctly if they know both the meaning of the words in question and the four multiple-choice options. It could capture the vocabulary size of the subjects. On the other hand, LexTALE is a real or pseudo-word judgment test that subjects could rely on their morphological knowledge or linguistic intuition. There is a growing consensus that L1 and L2 lexical items are activated simultaneously (Dijkstra & Van Heuven, 2002; Spivey & Marian, 1999; Thierry & Wu, 2007). Furthermore, according to the Inhibitory Control Model, bilinguals have to inhibit the unwanted language in order to produce the word in the target language. In other words, bilinguals must possess both lemmas of the same concept first, otherwise no lexical competition is needed. If the model is true, then vocabulary size might be one of the most important factors that determine how often or how effortful the linguistic inhibition is. Our findings supported this hypothesis, suggesting that vocabulary knowledge of the L2 is an essential factor in gaining bilingual advantage.

***Age-related decline in inhibition***

It is well-established that age significantly affects the performance of the Stroop task (Cohn, Dustman, & Bradford, 1984; West & Alain, 2000). In support of this view, a negative correlation between age and Stroop CW score was found in this study. However, when the other variables were considered in the multiple regression model to predict CW, age was not a significant variable. In contrast, age was one of the significant predictors in the models predicting the score in W and C conditions with the same variables as predictors using the same procedure. It suggested that age slowed down the speed of processing. However, the contribution of age to inhibition was partially influenced by L2 proficiency. The result is in line with previous literature that supports bilingualism could compensate for age-related cognitive decline (for review, see Guzman-Velez & Tranel, 2015). For instance, an fMRI study found that older bilinguals showed less activation in the left lateral frontal cortex and cingulate cortex, while behaviorally performing better than their monolingual counterparts (Gold, Kim, Johnson, Kryscio, & Smith, 2013). Similarly, Goral et al. (2015) found that bilingual older adults recruited less frontal regions than monolingual counterparts, but performed the Simon task with similar accuracy. The two studies suggested that lifelong bilingualism built up cognitive reserve, which helps them to maintain cognitive control ability in older age.

***Comparison of monolinguals and bilinguals***

As discussed in the introduction, monolinguals and bilinguals varied in their education levels. It was because all formal education taught English as second language, so no one with sufficient education would be monolingual. Still, learning does not always mean mastering. Six subjects indicated that had learnt English, but were not able to score any marks in the Shipley Vocabulary Test. It was probably because they were not using the language at all in their life-long career and eventually lost it. In fact, most of the monolinguals recruited were homemakers or clothing factory workers, who did not need to use English at all. In contrast, bilinguals were those who studied to a higher education level and worked in more complicated occupations, such as engineers, salesmen and teachers who needed to use English more often. It might be the socio-economic status during their youth that hindered some of them from continuing their studies. Even though they were the same generation living in the same place, they might have very different life experience which was known to affect cognition in old age (Stern, 2012). As reflected in the MoCA score, the two groups also differed in their cognitive status though they were all classified as cognitively normal based on the norms in their respective age and education levels. With such background differences, we hesitated to compare the two groups directly.

In the Stroop task, monolinguals and bilinguals were significantly different in color-word condition, but not in word or color conditions. The results suggested the two groups had similar naming speed but differed in suppressing interference. It should be noted that the monolinguals in this study were not pure monolinguals who were never exposed to an L2, and not all of our bilinguals were fluent in communicating in the L2. Yet, with the background differences discussed above, we do not wish to draw a concrete conclusion that the Stroop results were solely caused by bilingualism. Therefore, the above analysis concerned the bilingual group only.

### *Limitation*

The most proficient subject in our study (Shipley = 31/40, LexTALE = 92.5%) was not the "balanced bilingual" recruited in the previous literature, and the least proficient subjects (Shipley: 1/40, LexTALE = 42.5) could hardly communicate in L2 in full sentences. However, this might be the more representative scenario in the world's bilingual population, as not all bilinguals use and master their two languages to the same degree. Following DeLuca et al. (2019)'s advice, we urge future research to see bilingualism as more than either monolingual or bilingual, but a continuum of language experience.

## Conclusion

This study aimed at studying the relationship between inhibition and bilingualism, particularly in the population that is fluent in L2 but use L1 dominantly in daily communication. Our results suggested that the better L2 proficiency, the better the inhibition ability. Our study provided supporting evidence to the Inhibitory Control Model, and that the increase of strength in their L2 facilitates practice of suppression. Our results also support the hypothesis that bilingualism contributes to cognitive reserve in protecting older adults from age-related cognitive decline. We anticipated that this study could encourage future research on bilingualism to extend to more diverse populations other than balanced bilinguals, in order to reveal a fuller picture of bilingualism.

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