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Learning a Foreign Language: A New Path to Enhancement of Cognitive Functions

Sara Shoghi Javan[1,2] · **Behzad Ghonsooly**[1]

Abstract The complicated cognitive processes involved in natural (primary) bilingualism lead to significant cognitive development. Executive functions as a fundamental component of human cognition are deemed to be affected by language learning. To date, a large number of studies have investigated how natural (primary) bilingualism influences executive functions; however, the way acquired (secondary) bilingualism manipulates executive functions is poorly understood. To fill this gap, controlling for age, gender, IQ, and socio-economic status, the researchers compared 60 advanced learners of English as a foreign language (EFL) to 60 beginners on measures of executive functions involving Stroop, Wisconsin Card Sorting Task (WCST) and Wechsler's digit span tasks. The results suggested that mastering English as a foreign language causes considerable enhancement in two components of executive functions, namely cognitive flexibility and working memory. However, no significant difference was observed in inhibitory control between the advanced EFL learners and beginners.

Keywords Cognitive flexibility · Executive functions · Acquired bilingualism · Natural bilingualism · Inhibitory control · Working memory

Introduction

Research on bilingualism has been conducted from several perspectives. In spite of the fact that bilingualism is a verbal experience, only a small number of studies have investigated how verbal processing occurs in bilinguals (Kuo and Anderson 2012). These studies mostly were aimed to assess bilingual's advantage in the verbal domain through metalinguistic tasks and measured children's ability to process structural features of a language. Davidson et al. (2010), for instance, used a grammaticality judgment task and came to the conclusion that the

✉ Sara Shoghi Javan
sarashoghi@yahoo.com

1 English Department, Ferdowsi University of Mashhad, Mashhad, Iran

2 No. 20, Faramarz abassi 13 St, Faramarz Abassi Blvd, Mashhad 91979-64643, Iran

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Urdu-English bilingual children outperformed their monolingual peers when asked to determine the grammatically incorrect sentences. In addition, Kuo and Anderson (2012) carried out research on the effect of bilingualism on the development of phonological awareness in children. The results proved that both passive and active bilinguals were superior to monolinguals in the process of learning the phonological patterns in a new artificial language. Despite the scarcity of studies of this type, research on nonverbal cognitive processes of bilinguals, in particular, their executive functions which control the performance of a number of partly related higher-order cognitive processes has been abundant (e.g., Salthouse et al. 2003).

The large bulk of research on cognitive functions of bilinguals has demonstrated that bilingualism initiates enhanced performance on a number of executive functioning tasks which assess executive processes such as attention, inhibition, monitoring, and switching (reviews in Bialystok et al. 2009; Hilchey and Klein 2011). This is clearly observable among early bilingual children who develop executive abilities earlier than their monolingual peers (Daniel et al. 2006). According to Bialystok (2007), since bilinguals live in a context where they confront both languages on no pre-specified basis, they need to have the ability to monitor the context and switch between the two representational systems quite rapidly. Furthermore, bilinguals constantly deal with two simultaneously active language systems, and hence in order to manage the two languages at their disposal and communicate efficiently, they need to concentrate on the required language system (target language) and inhibit the interference of the non-target one. Bialystok and Martin (2004), stressing the necessity of inhibiting the unused language system, claimed that early bilingualism fosters children's ability to control attention.

Even though executive functions are developed through bilingualism in children, its assets are not limited to this age group. In other words, the constant challenge of controlling attention to the required system and inhibiting the interference of the unused language makes cognitive control function resistant against normal aging decline and postpones its deterioration (Bialystok 2007; Bialystok et al. 2004, 2008; Bialystok and Viswanthan 2010). Bialystok et al. (2004) compared monolingual and bilingual middle-aged and older adults and proved that the negative effects of aging in cognitive control were diminished by bilingualism. In addition to enhancement in attentional control, working memory is also assumed to be related to this function. Working memory mainly deals with storage and processing of information in cognitively complicated tasks which require ignoring irrelevant information and concentration on specific aspects (a practice that is routinely experienced by bilinguals); therefore, researchers have also suggested a working memory advantage for bilinguals (Miyake and Shah 1999; Namazi and Thordardottir 2010).

The studies discussed above were all conducted on natural bilinguals, i.e. their participants had all learned the language in-context and for real-life purposes. The terms primary and acquired/secondary bilingualism were suggested by Hoffmann (1991) to categorize types of bilingualism in terms of context. According to this categorization, primary bilingualism occurs when a child acquires a language without direct instruction and from the speakers around him. On the other hand, acquired/secondary bilingualism refers to learning a second language through formal teaching with little chance to practice it outside the classroom context. Wölck (1987) also made a similar distinction using the terms natural versus simulated/artificial bilingualism. Moreover, other researchers such as Alder (1977) and Krashen (1982) used the terms natural versus primary, and school versus cultural bilingualism, respectively, to introduce the same categorization.

The present researchers also believe that bilingualism can be best categorized as natural versus acquired in the context of Iran where almost all learners of English at any age need to undergo direct instruction with very little chance if any to use the language in a natural environment or for real-life purposes. Therefore, it is a matter of investigation whether the cognitive development that learning a second language in a natural learning context brings about occurs in the same way as learning a foreign language (through instruction) does.

Furthermore, there are claims regarding the causal relationship between cognitive functioning and language development. Kapa and Colombo (2014) conducted research focusing on the bidirectionality of the relationship between bilingualism and executive functions. They tested whether adults' and preschool children's EF abilities could predict success in learning a novel artificial language. They believed that while employing two languages might improve EF, higher EF skills might also assist language learning. The results obtained from this study suggested that inhibitory control ability predicted adults' artificial language performance (Study 1) and attentional monitoring and shifting ability predicted children's performance (Study 2). These findings showed that EF processes may be utilized during initial stages of language learning, specially vocabulary acquisition, and support the possibility of a bidirectional relationship between EF and language acquisition. That is to mean, "individuals with better EF are better language-learners, and [the] experience [of] controlling two language systems improves domain-general EF abilities (p. 249)".

Regarding the effect of executive functioning on second language learning, Atkins and Baddeley (1998) found out that among adult L2 learners, phonological working memory correlated with the number of L2 words successfully learned. On the other hand, the effect of language ability on cognitive development has been confirmed through both behavioral (Poulisse 2000; Schwartz and Kroll 2006) and neuroimaging evidence (Abutalebi et al. 2007; Christoffels et al. 2007; Hoshino and Thierry 2011; Jeong et al. 2007; Marian et al. 2003; Misra et al. 2012; van Heuven et al. 2008, cited in Kapa and Colombo 2014). The researchers believed that since bilinguals' other languages are simultaneously activated when they speak or listen to one of their languages, it is hypothesized that bilinguals use cognitive control processes to keep control over their two languages.

The present researchers also faced the same challenge concerning the causal relationship between cognitive development and language ability in foreign language learners (acquired bilinguals). While natural bilingualism has been widely studied, few researchers have investigated the interaction between acquired bilingualism and the brain or cognitive development. Martensson et al. (2012) studied the brain after foreign language learning and came to the conclusion that there is greater flexibility in the structure of the right hippocampus and the left superior temporal gyrus in foreign language learners. They also observed larger grey matter density in the middle frontal gyrus. This study can be taken as evidence that learning a foreign language improves the brain structurally. Drawing on the results obtained by Martensson et al. (2012), the present research is also based on the probable effect of language learning on cognitive development and aims at finding the answers to the following research question:

Is there a significant difference in the performance of advanced EFL learners and beginners on the measures of working memory, cognitive flexibility, and inhibitory control?

Methods

Participants

The present study aims at comparing the performance of Iranian advanced learners of English as a foreign language (EFL) and their early beginner counterparts on measures of executive functions. A sample of 60 advanced EFL learners and 60 early beginner EFL learners in the same age range (Mean = 16.4, $SD = 0.6$) were selected. While the advanced learners had been studying English for at least six consecutive years in private language institutes, the beginners had no experience of going to private English schools and had just relied on the basic English program provided by school.

It is noteworthy that, the educational system in Iran offers a 90-minute English program per week for 6 school-year which starts at age 12. This program is considered to be absolutely inefficient mainly due to untrained teachers, inappropriate, outdated materials and procedures, and also the large number of students in each class (e.g. Jamali 2008 and Ahmadpour 2004). Consequently, students who need to learn English have to enroll in private language institutes which offer English courses for all age groups and are held about 6 h a week. Therefore, students who do not attend private language institutes are considered beginners even after taking the course at school for 6 years. In the present study the participants were all female and took part in the research project voluntarily. Furthermore, the independent samples t-test was run to compare the IQ of the two groups. As the result showed, no significant difference was observed between the advanced EFL learners ($M = 123$, $SD = 8.16$, range: 34) and the beginners ($M = 124.5$, $SD = 6.3$, range: 26), $t(110.9) = 1.17$, $p = 0.242$ in their IQ. To control for other factors that may affect the development of executive functions in the participants, a background questionnaire was designed to obtain information regarding previous learning experiences, frequent recreational activities and family background (including educational level, job, and average income). Both groups belonged to the middle class of society regarding the income and educational level.

Materials

Background Questionnaire This questionnaire was designed by the present researchers to control for factors that affect executive functioning. These factors include the participants' lack of second language knowledge (i.e., a language learned in-context and without instruction), their previous learning experiences, frequent recreational activities, and family background (i.e., number of children, parents' jobs and education, and their average income).

Raven's Progressive Matrices Raven's Progressive Matrices is a measure of general nonverbal intelligence and is used to make sure participants are at a similar intellectual level. The booklet comprises five sets (A to E) of 12 items (e.g., A1 through A12). It is noteworthy that items within a set become increasingly difficult as the test goes on and require greater cognitive capacity to be encoded and analyzed. All items are presented in black ink on a white background.

In addition to the materials mentioned above, measures of executive functions were also utilized which included three computer programs examining the three components of executive functions.

Digit Span This task is similar to WISC-R (Wechsler 1974) and was used as a rough measure of working memory. This study utilized two forms of digit span tasks, namely visual and auditory. A Persian computerized version of the test was used in order not to add to the difficulty level of the task for the beginners. Each task of digit span yielded results regarding two variables, i.e. forward and backward. Regarding the visual task, in the forward digit span the participants were presented with a series of digits (1–9) appearing one by one in the middle of the screen. They were required to keep in mind the string of digits and choose them in the order they were presented from a list of numbers that appeared on the screen by means of a mouse. For each string there were two trials for the participant. The test was programmed to stop in case of participants' failure to remember a set of numbers in both trials correctly. Following a similar procedure, the backward digit span required the participants to keep in mind the string of digits and choose them in the *reverse* order.

The same process was followed in the auditory digit span task. This test also included forward and backward digit span tasks. However, this time the digits were read to the participants and they had to listen to them carefully to keep the strings of numbers in mind and choose them from the list of digits that appeared on the screen, either in the order they were presented (forward) or in the reverse order (backward). In both auditory and the visual digit span tasks, the forward condition started with a 3-digit string, the backward started with a 2-digit string, and continued to a maximum of a 12-digit string.

Wisconsin Card Sorting Task (WCST) This study utilized a computerized version of Wisconsin Card Sorting Task which is the most widely used measure of cognitive flexibility. The task consisted of 128 cards differing in number (1, 2, 3, 4), color (green, red, yellow, blue) and form (circle, triangle, star, cross) of the shapes printed on them. For example, while one card showed three red triangles, two yellow circles were displayed on another card. Four stimuli cards were presented next to each other on the top of the screen, and one response card appeared per trial in the middle of the screen. The participants were required to match the response card to one of the four stimuli cards based on a rule that they would discover by the "correct" and "incorrect" feedback they received. The sorting rule changed without notice and the participants were required to adapt the new rule. The scoring included several variables:

Perseverative errors Continuing to sort according to the previous rule despite the obvious discrepancy;

Perseverative responses the number of incorrect responses that would have been correct for the preceding rule;

Non-perseverative errors all the remaining incorrect responses other than the perseverative errors;

Categories completed the number of runs of ten correct responses. In this version, it ranges from 0 where the participant has no idea of what to do, to a maximum of 9 where the test ends;

Categories experienced the last category where the test ends, whether or not the participant has completed it;

Perseverative runs the number of error perseverations in a row at the beginning of each new category.

Stroop Color-Word Test Stroop (1935) is known as one of the most widely employed tests of selective attention and inhibitory control. The Persian computerized version of this test, consisting of two stages, was utilized in this study. The first stage, color-naming, was designed for the participants to get familiar with the colors and their place on the keyboard. A circle in blue, red, green, or yellow appeared in the middle of a black screen. The participants were required to press the button representative of that color on the keyboard as quickly as possible. In the second stage, the main stage of the Stroop test, the participants were presented with the Persian translation of the words blue, red, yellow, and green. Since half of the participants (i.e., early beginners) were not familiar with English, the Persian version of this test (Najarian and Barati Sedeh 1993) was administered to both groups. When the test was run one of the words, blue, red, green, or yellow, appeared in the middle of the screen in a congruent (where the word and font color corresponded) or incongruent (where color names were presented in conflicting font colors) condition, i.e., blue written in blue (congruent), or in yellow (incongruent). A total of 48 congruent and 48 incongruent words were presented. Each word was presented for 2 s and after that there was an 800 ms interval for the next trial to start. The participants were required to ignore the meaning of the word and just press the button which was representative of the font color that appeared on the screen. The reaction time was recorded for the congruent and incongruent conditions, and the interference number was calculated by subtracting the number of congruent correct responses from incongruent correct responses.

Results

The statistical analysis for the three components of executive functions, namely working memory, cognitive flexibility and inhibitory control are reported below. To determine the most suitable statistical methods to apply for data analysis, i.e., parametric or non-parametric, the first step was to identify whether the data were normally distributed. In the present study the normal and non-normal distribution of the data was verified through determining the skewness, standard error of skewness, kurtosis, and standard error of kurtosis. In addition, the one-sample Kolmogorov–Smirnov was used to ascertain the normal distribution of the data. In this case, a p-value of less than 0.05 asserted a non-normal distribution. Considering the results of the normality tests, the data were analyzed through appropriate parametric and non-parametric tests. To determine whether the two groups, i.e., advanced EFL-learners and beginners, were different from each other, the variables with normal distribution of data were analyzed through the independent samples t-test, and the variables with non-normal distribution were analyzed through its nonparametric counterpart, Mann–Whitney U test. To determine the power of the differences observed in the means, the effect size for each one was assessed.

Working Memory

Wechsler measure of working memory includes auditory and visual digit span tasks which are analyzed separately as follows:

Auditory Digit Span In this study working memory was assessed from two perspectives, i.e. auditory and visual. The data were normally distributed. However, to choose the appropriate test, both parametric and non-parametric tests were performed and it was decided that the non-parametric alternative to t-test, i.e. Mann–Whitney U, best suited the digit span data.

The results obtained from Mann–Whitney U test (Table 1) confirmed that the advanced EFL learners ($Mdn = 8$) performed significantly better than the beginners ($Mdn = 6$) on the forward auditory digit span task ($U = 907$, $Z = -4.73$; $p < 0.001$). Moreover, the advanced EFL learners ($Mdn = 9$) did significantly better than the beginners ($Mdn = 6$) on the backward auditory digit span task ($U = 640$, $Z = -6.1$, $p < 0.001$), too.

The performance of the participants on the forward auditory digit span task was a determinant of their auditory digit span score. As shown in Table 2, the advanced EFL learners ($Mdn = 7$) had a greater auditory digit span than the beginners ($Mdn = 5$) ($U = 991.5$, $Z = -4.3$, $p < 0.001$). The effect sizes obtained for forward auditory span ($r = -0.43$), backward auditory span (-0.55) and auditory digit span (-0.4), verified the

Table 1 Descriptive statistics and Mann–Whitney *U* test for auditory digit span

	Mdn	Mean	Mann–Whitney *U*	Z	Sig.	Effect size (r)
Forward auditory			907	−4.73	0.000	−0.43
Advanced EFLL	8	7.8				
Beginner	6	6				
Backward auditory			640	−6.1	0.000	−0.55
Advanced EFLL	9	8.3				
Beginner	6	5.8				
Auditory span			991.5	−4.3	0.000	−0.4
Advanced EFLL	7	6.45				
Beginner	5	5.45				

Table 2 Descriptive statistics and Mann–Whitney *U* test for visual digit span

	Mdn	Mean	Mann–Whitney *U*	Z	Sig.	Effect size (r)
Forward visual			803	−5.2	0.000	−0.5
Advanced EFLL	10	9.2				
Beginner	6	6.6				
Backward visual			942	−4.5	0.000	−0.4
Advanced EFLL	10	9.9				
Beginner	8	7.7				
Visual span			924	−4.7	0.000	−0.42
Advanced EFLL	8	7.2				
Beginner	6	5.9				

superiority of the advanced EFL learners to the beginners, especially in the case of backward auditory span.

Visual Digit Span Similar to auditory digit span, Kolmogorov–Smirnov test of normal distribution was conducted. The skewness and kurtosis were considered and both parametric and non-parametric tests were carried out. It was concluded that non-parametric Mann–Whitney *U* test was a better choice.

The results of Mann–Whitney *U* test, as shown in Table 2, indicated that the advanced EFL learners ($Mdn = 10$) significantly outperformed the beginners ($Mdn = 6$) on forward visual digit span task ($U = 803,\ Z = -5.2,\ p < 0.001$). Furthermore, the performance of the advanced EFL learners ($Mdn = 10$) and the beginners ($Mdn = 8$) on backward visual span task was examined and the superiority of the former was certified ($U = 942,\ Z = -4.5,\ p < 0.001$). Furthermore, it was revealed that the visual digit span of advanced EFL learners ($Mdn = 8$) far exceeded the beginners ($Mdn = 6$), ($U = 924,\ Z = -4.7,\ p < 0.001$). The effect size for forward visual digit span (−0.5), backward visual digit span (−0.4), and visual digit span (−0.42) acknowledged the magnitude of difference between the two groups. In visual section, unlike auditory, the excellence of the advanced EFL learners was more significant in forward rather than the backward digit span. The results obtained in this

Table 3 Descriptive statistics and Mann–Whitney *U* test for the variables with non-normal distribution in the Wisconsin Card Sorting Task as a measure of cognitive flexibility

	Mdn	Mann–Whitney *U*	Z	Sig.	Effect size (r)
Correct response		880	−4.9	0.000	−0.4
Advanced EFLL	101				
Beginner	90				
Total error		708.5	−5.7	0.000	−0.5
Advanced EFLL	22.5				
Beginner	38				
Perseverative response		1198	−3.2	.002	−0.3
Advanced EFLL	41				
Beginner	45.5				
Perseverative error		1015	−4.1	0.000	−0.4
Advanced EFLL	14				
Beginner	19				
Non-perseverative error		942	−4.5	0.000	−0.4
Advanced EFLL	8				
Beginner	13				
Unique error		1486.5	−2.05	0.04	−0.2
Advanced EFLL	0				
Beginner	0				
Categories experienced		768.5	−5.7	0.000	−0.5
Advanced EFLL	9				
Beginner	6				
Categories completed		746.5	−5.6	0.000	−0.5
Advanced EFLL	8				
Beginner	5				

section confirmed that the advanced EFL learners significantly outperform the beginners in their performance on the measures of working memory.

Cognitive Flexibility

Non-parametric Mann–Whitney *U* test was used for the analysis of all components, except for total perseverative run, which showed more significant results through the independent samples *t*-test. The analysis revealed that the advanced EFL learners showed greater cognitive flexibility than the beginners. The participants' performance on the WCST yielded the following results (Table 3):

the advanced EFL learners ($Mdn = 101$) had significantly a larger number of correct responses than the beginners ($Mdn = 90$), ($U = 880,\ Z = -4.9,\ p < 0.001$);

the advanced EFL learners ($Mdn = 22.5$) made fewer errors than the beginners ($Mdn = 38$), ($U = 708.5,\ Z = -5.7,\ p < 0.001$);

the advanced EFL learners ($Mdn = 41$) committed fewer perseverative errors than the beginners ($Mdn = 45.5$), ($U = 1198,\ Z = -3.2,\ p = 0.002$). It is noteworthy that, making perseverative errors is one of the most notable indicators of low cognitive flexibility;

Table 4 Descriptive statistics and *t*-test for variables with normal distribution of data in the Wisconsin Card Sorting Task as a measure of cognitive flexibility

	M	SD	df	t	Sig.	Effect size (η^2)
Total perseverative run			112.4	4	0.000	0.1
Advanced	13.05	3.8				
Beginner	9.8	4.8				

the advanced EFL learners ($Mdn = 8$) also made fewer non-perseverative errors than the beginners ($Mdn = 13$), ($U = 942,\ Z = -4.5,\ p < 0.001$);

The advanced EFL learners managed to experience more categories ($Mdn = 9$) than the beginners ($Mdn = 5$), ($U = 768.5,\ Z = -5.7,\ p < 0.001$) and also complete ($Mdn = 8$) more categories in comparison to the beginners ($Mdn = 6$) ($U = 746.5,\ Z = -5.6,\ p < 0.001$). That is, due to higher cognitive flexibility, the advanced EFL learners could perform more successfully and proceed in the task more than the beginners. Calculation of effect size yielded large effect sizes for total error, categories experienced, and categories completed (−0.5), above average effect size for correct response, perseverative error, and non-perseverative error (−0.4), and average effect size for perseverative response (−0.3).

Furthermore, the independent samples *t*-test (Table 4) revealed that the perseverative runs were observed more significantly among advanced EFL learners ($M = 13.05,\ SD = 3.8$) and to a lower extent among the beginners ($M = 9.8,\ SD = 4.8$), $t(112.4) = 4,\ p < 0.001$. The large eta squared effect size ($\eta^2 = 0.1$) asserted the magnitude of this difference. The statistical analyses confirmed the outstanding superiority of the advanced EFL learners on the measure of cognitive flexibility.

Selective Attention and Inhibitory Control

Considering the results obtained from the Kolmogorov–Smirnov Z, skewness and kurtosis, the analysis of four components of Stroop test (i.e. congruent error, incongruent error, congruent correct response, and incongruent correct response) was done through Mann–Whitney *U* test, and three components, namely congruent reaction time, incongruent reaction time, and difference in reaction time were analyzed using the independent samples t-test.

As shown in Table 5, Mann–Whitney *U* test yielded Stroop group differences in favor of beginners, that is the advanced EFL learners made more congruent ($U = 1417.5,\ Z = -2.3,\ p < 0.05$) and incongruent ($U = 1370.5,\ Z = -2.4,\ p < 0.05$) errors than the beginners. Therefore, the beginners had more congruent ($U = 1427,\ Z = -2.2,\ p < 0.05$) and incongruent ($U = 1351,\ Z = -2.5,\ p < 0.05$) correct responses. However, the interference score which was obtained from subtracting the number of incongruent correct responses from congruent correct responses showed no significant difference between the two groups ($U = 1581.5,\ Z = -1.2,\ p = 0.2$). Although the Mann–Whitney *U* test suggested that there were significant differences between the two groups, the effect size of −0.2 revealed that, the differences were small.

Considering the reaction time, the independent samples *t*-test showed that there was no significant difference between the advanced EFL learners ($M = 856.8,\ SD = 118.3$) and the beginners ($M = 863.5,\ SD = 107.2$), $t(118) = -0.3,\ p = 0.7$, in congruent reaction time (Table 6). Similarly, no significant difference was observed between the advanced EFL learners ($M = 896.7,\ SD = 131.7$) and the beginners ($M = 898.9,\ SD = 116.9$), $t(118) =$

Table 5 Descriptive statistics and Mann–Whitney *U* test for variables with non-normal distribution of data in the Stroop task

	Mdn	Mean	Mann–Whitney *U*	Z	Sig.	Effect size
Congruent error			1417.5	−2.3	0.02	−0.2
Advanced EFLL	0	0.85				
Beginner	0	0.45				
Incongruent error			1370.5	−2.4	0.01	−0.2
Advanced EFLL	1	1.13				
Beginner	0	0.6				
Congruent correct response			1427	−2.2	0.03	−0.2
Advanced EFLL	47.5	47.06				
Beginner	48	47.5				
Incongruent correct response			1351	−2.5	0.01	−0.2
Advanced EFLL	47	46.7				
Beginner	48	47.3				
Interference score			1581.5	−1.2	0.2	−0.1
Advanced EFLL	0	0.4				
Beginner	0	0.2				

Table 6 Descriptive statistics and *t*-test for variables with normal distribution of data in the Stroop task

	Mean	SD	t	df	Sig.	Effect size (η^2)
Congruent reaction time			−0.3	118	0.7	0
Advanced EFLL	856.8	118.3				
Beginner	863.5	107.2				
Incongruent reaction time			−0.09	118	0.9	0
Advanced EFLL	896.7	131.7				
Beginner	898.9	116.9				
Difference in reaction time			0.6	118	0.5	0
Advanced EFLL	39.8	45.4				
Beginner	35.3	34.5				

-0.09, $p = 0.9$ in incongruent reaction time. Moreover, the difference in reaction time which was obtained by subtracting the incongruent reaction time from the congruent reaction time yielded no significant difference between the advanced EFL learners ($M = 39.8$, $SD = 45.4$) and the beginners ($M = 35.3$, $SD = 34.5$), $t(118) = 0.6$, $p = 0.5$. As it was expected, the effect size of 0 confirmed the results. Indeed, inhibitory control turned out to be of almost similar strength in the advanced EFL learners and beginners.

Discussion

This study is mainly in line with the studies which examine the effect of language learning on cognitive development (e.g. Schlegel et al. 2012; Bialystok et al. 2014; Kuo and Anderson

2012). However, the novelty revolves around the idea that foreign language learning may demand mechanisms that are unlike learning a second language, and consequently may affect cognitive functions in a different way. The participants' executive function abilities were measured through three tasks that tap into the components of executive function, i.e. working memory, cognitive flexibility and inhibitory control. The results are discussed below:

Working Memory

One of the most crucial components of executive functions is working memory whose foremost function is the retention and processing of verbal information. Generally, learning a second or foreign language (in this case English) is deemed to increase this capacity. Such improvement occurs because of the need to have two sets of linguistic representations available and seek resort to them. In the present study, working memory, as measured by Wechsler's auditory and visual digit span tasks, was proved to be of significant superiority in the advanced EFL learners. That is, not only did the advanced EFL learners have a greater auditory digit span than the beginners but they also had a greater visual digit span than the beginners. The visual task seemed to be proportionally easier for both the advanced EFL learners and beginners in comparison to the auditory task. Furthermore, while the advanced EFL learners performed similarly on both forward and backward visual digit span tasks, in the case of the auditory task, they performed better on backward in comparison to forward task.

As shown in the results, working memory was proved to be remarkably enhanced by foreign language learning. What causes this superiority is required to be carefully investigated since natural bilinguals are very different from acquired bilinguals in terms of their learning procedures. This advantage may be rooted in the persistent effort of the advanced EFL learners during their 6-year experience of attending language classes, and being trained under certain teaching methodologies. A common activity that is deemed to cause such enhancement is listening comprehension exercises in which students are required to repeat what they hear chunk by chunk, or in higher levels, sentence by sentence. Drilling which requires retention and on-line manipulation of information also draws on working memory. The learners have to keep in mind the main sentence, actively change a part as the teacher instructs, and restate the sentence in its new form. Furthermore, reading comprehension exercises require learners to understand the text, make inferences, and identify and keep in mind the important arguments. No doubt, this is the task of working memory to restore and manipulate the strings of written words to make them meaningful and make even complicated inferences possible. Moreover, the attempts to memorize the meaning of new words, accessing them from its repertoire to be used in a context, learning structures and trying to substitute words in appropriate structural forms all draw on working memory and lead to its development.

Cognitive Flexibility In addition to working memory, cognitive flexibility is a constituent of executive functions that has a determining role in individuals' behavior. It is the ability to change perspectives, think outside the box, and nimbly adjust to altered demands or priorities (Diamond et al. 2007). Wisconsin Card Sorting Task (WCST) was used as a measure of cognitive flexibility. It measures several variables, out of which perseveration is the most determining one. According to Lezak (1982), perseveration is related to deficits in execution of activities. For instance, failure to initiate, maintain, change or stop an action when it is required is a sort of perseverative error. Brace et al. (2006) investigated the reason of perseveration in healthy individuals and reported that weakness in working memory can permit latent memory to supersede working memory and cause perseverative errors.

The results obtained from the WCST confirmed that the advanced EFL learners significantly outperformed the beginners in cognitive flexibility. In fact, the advanced EFL learners had more correct responses than the beginners and made fewer perseverative and non-perseverative errors. Furthermore, although there was a significant difference in the number of unique errors made by the two groups, the effect size was small. As mentioned earlier, this task involves a maximum of 9 categories where each category requires 10 consecutive correct responses. Each participant, depending on her performance, may not be able to complete even one category or complete as many as 9. In this study, the advanced EFL learners managed to complete more categories than the beginners. *Categories experienced* also refers to the last category in which the test ends, whether or not the participant has completed it. Similar to the *categories completed*, the advanced EFL learners remarkably outperformed the beginners in this item, too.

The main causes of enhanced cognitive flexibility are understanding the conventional relationship between words and their referents, accepting and employing linguistic structures different from their own, and familiarity with cultures and behaviors that sound exotic (Hakuta and Diaz 1985). Similar to natural bilinguals, foreign language learners go through different stages of language internalization. Research on bilingualism has suggested that bilinguals benefit from higher cognitive flexibility which has been asserted by observing that they outrank monolinguals in both verbal and nonverbal tasks (Ben-Zeev 1977; Peal and Lambert 1962). The recognition of the conventionality of words and their meanings, and willingness to adopt the new linguistic system is a great practice for cognitive flexibility. It is generally observed that, at earlier stages of language learning, learners resist the employment of linguistic rules and structures which contrast those present in their own repertoire. However, as they progress, due to enhanced metalinguistic awareness they become more and more flexible. To unravel other causes of this high amount of flexibility among foreign language learners extensive research is required.

Inhibitory Control Inhibitory control is the ability to ignore some information or suppress a more potent response in order to concentrate on other relevant information for completing a cognitive task (Kapa and Colombo 2014). Several studies have verified the significant advantage of natural bilinguals in inhibitory control and selective attention (e.g. Bialystok 2007; Bialystok and Martin 2004; Daniel et al. 2006). The results from the Stroop task revealed that unlike working memory and cognitive flexibility that were remarkably developed among foreign language learners, there was no sign of superiority in inhibitory control among them. It seemed that foreign language learners had not undergone enough practice to improve their inhibitory control.

Contrary to cognitive flexibility and working memory that showed considerable improvement in the advanced EFL learners, inhibitory control was proved to be at a similar level in both groups. This finding, however, can be logically explained by drawing attention to the fact that, learning a second language in context forces the learners to practice shifting from one language to another quite more often than foreign language learners whose use of second language is restricted to classroom context, and they rarely if ever find the chance to communicate for real-life purposes in a natural context. Although at the early stages learners are required to inhibit their first language while trying to speak in the second language, this effort seems not adequate for a considerable boost in inhibitory control. Witnessing natural bilinguals' enhanced inhibitory control and selective attention, the large capacity of language learning for improving these functions is verified. Given that, providing tasks and exercises that stimulate aggregate demand and effort in learners, would probably reinforce their concentration, make them more fluent speakers and meticulous readers.

The difference between natural bilinguals and foreign language learners in their dominance over a second language may lie in their diverse inhibitory control abilities. It is widely observed that a large number of advanced language learners despite having considerable knowledge and ability cannot perform well in tasks of reading comprehension, listening, or speaking. This weakness may be rooted in their cognitive capacity which can no longer respond to the requirements of this huge system. Internalizing a second language imposes enormous pressure on the brain, and its efficient operation requires fortified brain functions. One can liken this to a new complicated program that needs an upgraded operating system to run. It is the task of experts in the field of language teaching and learning to recognize the cognitive requirements of language learning, and design materials to fortify them with an upgraded cognitive system.

Conclusions

Depending on the extent and type of motivation that foreign language learners have, and considering the difficulties of learning a foreign language in classroom context, it is a matter of discussion whether all learners would persist to higher levels of language learning or they would give it up half-way. Iran is a country where English is rarely used, except for specific academic purposes; however, because it is an international language most people eagerly spend a lot of time, money and energy on learning it in private language institutes. In line with the results obtained by Martensson et al. (2012), this study showed that the language learners' effort had led to enhancement in cognitive flexibility and working memory, but not in inhibitory control. While in the present study the researchers attempted to assess the effect of language learning on cognitive development, it is strongly suggested that this issue be studied from the opposite angle, i.e. the effect of cognitive ability on foreign language learning. Nevertheless this question remains unanswered whether these advanced learners were cognitively superior from the beginning and this asset had made them progress to advanced levels, or the very experience of language leaning had caused such enhancement.

Compliance with Ethical Standards

Conflict of interest The authors declare that they have no conflict of interest.

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