



THE UNIVERSITY *of* EDINBURGH

Edinburgh Research Explorer

Cognitive advantages of immersion education after 1 year

Citation for published version:

Puric, D, Vuksanovi, J & Chondrogianni, V 2017, 'Cognitive advantages of immersion education after 1 year: Effects of amount of exposure' *Journal of Experimental Child Psychology*, vol. 159, pp. 296-309. DOI: 10.1016/j.jecp.2017.02.011

Digital Object Identifier (DOI):

[10.1016/j.jecp.2017.02.011](https://doi.org/10.1016/j.jecp.2017.02.011)

Link:

[Link to publication record in Edinburgh Research Explorer](#)

Document Version:

Peer reviewed version

Published In:

Journal of Experimental Child Psychology

General rights

Copyright for the publications made accessible via the Edinburgh Research Explorer is retained by the author(s) and / or other copyright owners and it is a condition of accessing these publications that users recognise and abide by the legal requirements associated with these rights.

Take down policy

The University of Edinburgh has made every reasonable effort to ensure that Edinburgh Research Explorer content complies with UK legislation. If you believe that the public display of this file breaches copyright please contact openaccess@ed.ac.uk providing details, and we will remove access to the work immediately and investigate your claim.



Cognitive Advantages of Immersion Education after One Year: Effects of Amount of
Exposure

Danka Purić, Jasmina Vuksanović and Vasiliki Chondrogianni

Faculty of Philosophy, Belgrade University

Author Note

Danka Purić, Psychology Department, Faculty of Philosophy, Belgrade University

Jasmina Vuksanović, Institute for Medical Research, Belgrade University

Vasiliki Chondrogianni, School of Philosophy, Psychology and Language Sciences,
University of Edinburgh

Correspondence concerning this article should be addressed to Danka Purić,
Psychology Department, Faculty of Philosophy, Belgrade University – 18-20 Čika Ljubina
Street, 11000 Belgrade, Serbia. Contact: dpuric@fbg.ac.rs

Word count (text + references): 8578

Abstract

Previous studies with bilingual children have shown that the nature of their L2 instruction has an effect on the development of their cognitive abilities. The aim of this study was to determine whether children who acquire a second language in two different immersion programs for a period of one year show advantages in executive functions and to examine how the amount of *daily exposure* affects executive functions. A group of Serbian-speaking second grade children exposed to the second language for five hours a day (high exposure group, HEG), and a low exposure group (LEG) exposed to the second language for one and a half hours a day were compared to an age-matched control group (CG) of monolingual peers on working memory, inhibition and shifting. Significant group differences were found for working memory, with the HEG performing better than the CG and the LEG, even after controlling for individual differences in terms of age and intelligence. The three groups did not differ in terms of inhibition and overall shifting abilities, although the control group had a marginally significant advantage on one of the two shifting tasks. Our findings extend previous research by demonstrating that the amount of daily exposure is a significant factor affecting executive functions in early immersion programs for second language acquisition. Additionally, they show that early intensive second language acquisition can be advantageous for performance on tasks that require a higher level of executive control.

Keywords: second language acquisition, working memory, inhibition, shifting, executive functions

Introduction

A large body of research has shown that bilingualism has a positive effect on cognitive development (Poarch & Van Hell, 2012; Carlson & Meltzoff, 2008; Martin-Rhee & Bialystok, 2008; Poulin-Dubois et al., 2011; Bialystok, 2011). The positive impact of bilingualism has been observed in a variety of tasks that require cognitive control components, such as selective attention (Bialystok, 2001), cognitive flexibility (Poulin-Dubois, Blaye, Coutya, & Bialystok, 2011), and engagement of working memory (WM) (Morales, Calvo & Bialystok, 2013). All of these cognitive control components fall under the umbrella term executive functions (EF), which encompasses three core abilities: *inhibition*, defined as either inhibition of prepotent responses or of incoming interference, *shifting*, which comprises mental set shifting or switching, and *working memory (WM)*, which involves information updating and monitoring (Miyake et al., 2000).

How could one explain this positive effect of bilingualism on executive functions? There is now overwhelming evidence that when we speak, both languages are active to some degree, even in contexts that clearly support only one of the languages (Francis, 1999; Rodriguez-Fornells, Rotte, Heinze, Nosselt, & Munte, 2002; Marian, Spivey, & Hirsch, 2003; Kroll, Bobb, & Wodniecka, 2006; Thierry & Wu, 2007). These studies suggest that there is a high probability of interference from the non-relevant language when the other one is in use as the two languages potentially compete for cognitive resources. In order not to erroneously use the unintended language or lose fluency in either of the languages, bilinguals must acquire a way to control or regulate that competition (Bialystok, 2001; Kroll, Dussias, Bice, & Perrotti, in press). In other words, bilingual individuals are placed in a situation where

executive control is required: while speaking, the speaker plan the content of their utterance taking into consideration the current topic and context (which requires working memory), selects relevant linguistic structures in one language (which requires inhibiting the competing structure of another language), monitors the progress of the interaction within a certain topic and removes from the storage system all content which was used but is no longer relevant for the conversation (which also requires working memory), and potentially switches between languages (which requires shifting).

To date, studies with bilingual children have primarily focused on one specific component, that of inhibition. However, the results from these studies have been controversial. Studies using the Stroop and the Simon tasks have found significantly better performance in bilinguals compared to their monolingual counterparts (e.g., Bialystok et al., 2004; Hernández et al., 2012). Martin-Rhee & Bialystok (2008), however, reported that bilinguals outperform monolinguals on a variety of tasks that require control over attention to competing cues (interference suppression), but not on tasks requiring inhibition of a habitual or prepotent response. Results obtained from recent studies with large sample sizes have further challenged the earlier research findings by showing no bilingual advantage in inhibitory control either in children or adults (Anton et al., 2014; Duñabeitia et al., 2014; Gathercole et al., 2014; see Valian, 2015 for a review of the relevant issues).

Recently, a shift has been made from viewing inhibition as the only cognitive control component relevant for bilingual language use to taking a more global overview of all EF components. Some of these studies have provided supporting evidence for bilingual advantages in shifting ability (Bialystok, 2010; Okanda, Moriguchi, & Itakura, 2010; Prior & MacWhinney, 2010), although these findings have not been replicated across studies (Paap

& Greenberg, 2013). A carefully conducted study by Xie (2014) suggested a more complex picture by showing that language use and language-switching experience, but not proficiency in the second language, significantly contribute to performance on tasks tapping shifting ability.

The controversy regarding bilingual advantages also extends to the third component of EF, working memory (Engel de Abreu, 2011; Engel de Abreu, Cruz-Santos, Tourinho, Martin, & Bialystok, 2012). According to Baddeley (1998), WM is a multicomponent, capacity-limited system which handles current demands for temporarily storing and managing the information required to carry out complex cognitive tasks. It is well established that WM performance is strongly related to language acquisition and processing (Archibald & Gathercole, 2006; Majerus et al., 2006). The central executive component is a flexible system responsible for the control and regulation of cognitive processes (Baddeley, 1998) which plays an important role in oral and written language processing (Seigneuric, Ehrlich, Oakhill, & Yuill, 2000; Cain, Oakhill, & Bryant, 2004; Daneman & Carpenter, 1980; Gathercole, Alloway, Willis & Adams, 2006). The phonological loop (short-term verbal memory), the most important domain-specific component of WM for language processing, includes a capacity-limited phonological short-term storage buffer and an articulatory control process that refreshes and maintains speech material in storage for a brief period (Montgomery, 2003). The phonological loop's main role in language acquisition and development is to temporarily store verbal input so it can be used for further processing (Baddeley, Gathercole & Papagno, 1998). In addition, short-term verbal memory performance is strongly related to language learning in both native and foreign languages

(Gathercole et al., 1997, 1999; Engel de Abreu, 2011, 2009; Majerus et al., 2006; Masoura & Gathercole, 2005).

There are reasonable grounds to believe that WM could be associated with bilingualism. Coping with the demands of controlling two languages might affect WM performance through its impact on the central executive component regardless of the modality (visuospatial or verbal). In other words, bilinguals may exhibit more efficient WM abilities than monolinguals because the bilingual environment provides EF training as a result of the continuous need to monitor which language to use in each communicative interaction, and to store and update this information. However, further research is needed to establish whether or not bilingualism has an effect on WM abilities (Hernández, Costa, & Humphreys, 2012). For example, Morales, Calvo and Bialystok (2013) found WM advantages in 5- and 7-year-old bilingual children in the Frogs Matrices task. In this task, children needed to remember the location of a frog in a pond. The bilingual advantage was especially prominent in the executive-loaded sequential condition that required recalling both the locations of the frog and the order of the locations. Similarly, Blom et al. (2014) reported a bilingual advantage for visuospatial and verbal WM in 5-to-6-year-old Turkish-Dutch-speaking children. Visuospatial working memory was assessed using the Dot-Matrix task from the Automated Working Memory Assessment (AWMA; Alloway, 2007). In this task, children were shown a series of screens on which a red dot appears in a matrix and were asked to recall the coordinates of the dots. Blom et al. also assessed verbal WM using the Forward Digit Recall and the Backward Digit Recall tasks. They found a bilingual advantage for the Dot-Matrix task and the Backward Digit Recall task; the bilingual advantage was also stronger for the Backward Digit Recall task, which requires both storage and processing, than

for the Dot-Matrix task, which is considered more of a visuospatial storage task.

Additionally, Bialystok & Feng (2009) reported that bilinguals outperformed monolinguals on memory recall tasks involving proactive interference – the situation where retrieval of recent material is impaired by prior exposure to similar items. In contrast, Engel de Abreu (2011) found no bilingual advantage for visuospatial WM although her tasks and population of bilingual children were very comparable to that in the Morales et al. (2013) study.

Research on factors responsible for the relationship between bilingualism and EF has demonstrated that the level of bilingual proficiency should also be accounted for – a more balanced level of proficiency in the two languages, together with more balanced language use, leads to better executive control skills, at least in bilingual adults (Luo, Luk, and Bialystok, 2010; Yow and Li, 2015).

Second language education and executive control

The majority of studies examining EF in bilingual children have compared monolingual children with children who have had a lifetime's experience with a second language (Bialystok et al., 2014; see Blom et al., 2014 for research on immigrant children). To date, only a handful of studies have investigated the interplay between EF and dual language development in bilingual children attending different second language education programs. Poarch & Van Hell (2012) studied EF in monolingual, bilingual and trilingual children as well as in children in the process of learning a second language. According to their results, second language learning children performed in between their monolingual and bilingual/trilingual peers. This finding suggested that enhanced executive control was emerging in the second language learners, but had not yet reached levels similar to those of the bilingual and trilingual children. In a recent study by Pelham and Abrams (2014),

however, early bilinguals who became fluent in the second language before 7 years of age and late bilinguals who became fluent in the second language from the age of 13 years onwards exhibited similar overall EF benefits, with both groups surpassing their monolingual peers in this respect. These results suggest that second language experience brings benefits to cognitive control in children despite different ages of L2 onset and, presumably, length of exposure. In another study, Luk et al. (2011) investigated the relationship between age of second language onset and EF in two groups of early and late bilinguals and found that the early bilinguals outperformed both monolinguals and late bilinguals, the latter two groups performing at a similar level. Apart from the obvious effect of age of second language onset, the authors interpreted these results as suggestive that “more experience in being actively bilingual is associated with greater advantages in cognitive control and higher language proficiency” (Luk et al., 2011: p.588).

However, as Bialystok et al. (2014) point out, what is less clearly understood is exactly when and how these advantageous effects surface in the context of emerging bilingualism. Studies comparing children in immersive education programs with children in monolingual education, although not fully comparable in terms of participant group selection (different age and spoken languages) or in terms of the experimental tasks used, have provided mixed results regarding the effect of length of exposure on EF (Bialystok, Peets, & Moreno, 2014; Carlson & Meltzoff, 2008; Nicolay & Poncelet, 2013). Bialystok and Barac (2012) and Bialystok et al. (2014) have shown that executive control performance improves as a function of increased language experience in an immersion program in 7-to-11 year old children. Nicolay and Poncelet (2013) found that 8-year old children enrolled in an immersion program for three years significantly outperformed their monolingual peers on

tasks assessing alerting, auditory selective attention, divided attention and mental flexibility, suggesting that three years of second-language immersion is sufficient to produce some of the executive benefits associated with early bilingualism. In their study of preschool children who had attended an immersion program for six months, Carlson and Meltzoff (2008) found that they did not differ from their monolingual peers on inhibition, shifting and working memory tasks. A possible interpretation of these findings could be that the level of language proficiency is the key variable through which language experience influences executive functions. Indeed, a positive relationship has been demonstrated between the level of language proficiency and performance on tasks tapping executive functions (Iluz-Cohen and Armon-Lotem, 2013).

The current study

Bearing in mind the studies mentioned above which showed that executive functions improved with increased language experience in a bilingual education program after three years (Bialystok & Barac, 2012), but not after six months (Nicolay & Poncelet, 2013), we proposed two hypotheses. Firstly, attending a second-language immersion program for a period of one year will bring about better EF abilities. Secondly, the *amount of exposure* will determine the size of the effect on EF. In order to test these hypotheses, we selected second grade Serbian-speaking children from two different immersion programs, a high exposure group of children who attended a program of second language acquisition for five hours a day and a low exposure group of children exposed to the second language for one and a half hours a day. The two groups were compared on working memory, inhibition and shifting to an age-matched control group of children attending mainstream monolingual schools in Belgrade. Our hypotheses predict that both immersion groups will outperform the

monolingual group on EF tasks, but the differences will be larger for the high exposure group.

Method

Participants

A total of 58 typically developing monolingual Serbian-speaking children were included in the sample: 19 in the high exposure group (HEG), 17 in the low exposure group (LEG) and 22 in the control group (CG). All children were Serbian nationals raised monolingually and their mean age was 7 years and 11 months ($SD=7$ months). The children in the HEG were attending international schools in Belgrade. These are immersion schools where all subjects are taught in a second language (either English or German) for about five hours each working day. At the time of testing, children in the HEG had attended immersive education for at least one year. The LEG consisted of children immersed in an intensive second language acquisition program within an experimental school with a gradually increasing number of second language lessons (French). During the first year, this program includes over six hours of second language classes each week, which roughly corresponds to one hour and twenty minutes every working day. The children in the sample had been enrolled in this program for over one year at the time of testing. The children in the CG attended standard monolingual Serbian-speaking primary schools in Belgrade. Schooling in Serbia starts at the age of seven years and all children were attending the second grade at the time of testing. The groups were also comparable in terms of socioeconomic background assessed by parental education. The school principals provided information on the percentage of parents that had completed high school (12 years of education) or university education (16 years of education in total). 12 mothers and 15 fathers in the HEG, 16 mothers and 17 fathers

in LEG and 19 mothers and 19 fathers in the CG had completed 16 years of education. Yates' corrected χ^2 indicated that there were no significant group differences in either maternal, $\chi^2 = .76, p = .68$ or paternal education, $\chi^2 = .19, p = .91$.

In order to be included in the study, participants also had to meet the following criteria: intellectual abilities between the 25th and the 90th percentile, normal hearing, normal or corrected-to-normal vision and no history of neurological disorders, behavioral problems, or any other psychopathological issues. The three groups did not differ in either their average age or intellectual abilities (Table 1).

Table 1

Subsample mean age and intelligence

	CG		LEG		HEG		<i>F</i>	<i>p</i>	η^2
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>			
Age in months	94.6	6.9	98.2	2.2	92.9	8.7	2.9	.07	.09
Raven's CPM	26.7	2.5	27.7	3.1	28.3	4.5	.99	.38	.45

CPM = Colored Progressive Matrices (age-corrected scores)

Materials

A comprehensive battery of executive function tests was administered to all participants along with a test of fluid intelligence. All executive function tasks were constructed and administered using E-Prime software (Schneider, Eschmann, & Zuccolotto, 2002) and were presented to participants on Acer Iconia Tab computers. The intelligence test was administered in a paper-and-pencil form.

Fluid intelligence. Children were administered the Raven's Colored Progressive Matrices test (Raven et al., 1986) in which they are required to complete a geometrical figure by choosing a missing piece from a list of six possible choices. The total number of items is 36. Every answer is scored as 1 when correct and 0 when incorrect, with a total maximum score of 36. The scores were age-corrected.

Working memory. Children completed two complex span tasks. Bearing in mind that WM tasks differ in modality and complexity, for the purposes of our study two complex WM tasks were selected, the Counting Recall task and the Backward Digit Recall task. Both tasks are verbal WM tasks; however, they were selected mainly because of their frequency of use and ease of administration. Both measures require participants to simultaneously process and store information. The number of items to be remembered increases progressively over successive blocks containing four trials each. Test administration stops if the child fails to correctly recall three trials in one block. Both span and the number of correct responses (task score) were used as dependent variables.

The *counting recall task* (working memory) was taken from the Serbian adaptation of the Automated Working Memory Assessment (AWMA¹, Alloway, 2007). Participants are presented with a varying number (four to seven) of red dots and blue triangles on the screen. Their task is to count the number of red dots and memorize it. The number of consecutive images shown before the recall phase varies from one to seven.

The *backward digit span task* (working memory) was taken from Huizinga, Dolan and Van der Molen (2006). In this task, participants hear a number sequence and are required

¹ The Automated Working Memory Assessment. Copyright © (2007) by Pearson Assessment. Serbian Translation Copyright © (2013) by Pearson Assessment. Translated & Reproduced with permission. All rights reserved.

to repeat it in reverse order. The sequences get progressively longer, ranging from two to eight numbers.

Inhibition².

The *nonverbal Stroop task* was taken from Lukács, Ladányi, Fazekas and Kemény (2015) and uses arrows pointing upwards, downwards, left and right as stimuli. The task has three blocks with 60 trials each. In the first (control) block the arrows are presented in the middle of the screen, in the second (congruent) block the arrows are presented in their corresponding positions on the screen (with the arrow pointing left on the left side of the screen, and so on) and in the third (incongruent) block arrows are presented on the opposite sides of the screen (with the arrow pointing left on the right side of the screen, and so on). The participants' task is to determine the arrow's orientation, regardless of its onscreen position, responding by pressing a button. The difference in reaction times for congruent and incongruent trials represents the inhibition cost.

Shifting. Participants were also administered two shifting tasks, each containing three blocks. In the first block, the child is required to respond to stimuli presented in the upper half of the screen by paying attention to one of the stimulus dimensions. In the second block, the same stimuli are presented in the lower half of the screen and the dimension that needs to be responded to is different. Finally, in the third, critical block, the child needs to alternate between the two dimensions, depending on the onscreen position of the stimulus (above or

² Initially, two tasks were used to assess inhibition. Unfortunately, due to a programming error causing participant responses not to be recorded, the other inhibition task (stop-signal task) had to be excluded from further analyses. The main drawback of this lack of data is that it makes the generalization of any registered effects less convincing than if two tasks had been used. Additionally, some previous studies (Carlson & Meltzoff, 2008; Martin-Rhee & Bialystok, 2008) have shown that bilingual children do not differ from monolingual children on measures of response inhibition, but do differ on measures of interference inhibition, although this finding is not always replicated (Bialystok, Barac, Blay, & Poulin-Dubois, 2010; Verhagen, Mulder, & Leseman, 2015). For that reason, although it would have made our design more balanced to have included this task, we do not think that it significantly compromises the importance of our findings.

below a horizontal line dividing the screen). Cues directing the participant to the relevant dimension are presented simultaneously with the stimuli on all trials, in all blocks. The first two blocks contain 32 trials each, while the third block contains 64. The number of shifting and non-shifting sequences within the third block is balanced. The difference in reaction times for the first two (non-shifting) and the third (shifting) block represents the general shifting cost. Local shifting cost is reflected by the difference in average RTs for shifting and non-shifting trials within the third block.

The *local-global task* (shifting) was adapted from Huizinga et al. (2006) and uses four complex figures shown in Figure 1. In the first block the participant's task is to respond to the shape of the larger figure (determining whether it is a square or a rectangle), in the second block their task is to respond to the shape of the smaller figure, and in the third (critical) block they must shift between the two response types.



Figure 1. Complex figures used as stimuli in the local-global task

In the *color-shape task* (shifting), developed for this research, participants are presented with the following four figures: blue/red triangles/circles. Within the first block, participants are required to respond to the shape of the stimulus, within the second to its color, and in the third block they need to alternate between the two types of decisions.

Procedure

Institutional approval for human investigation was received before the participants were tested. All parents gave informed written consent for their children to take part in the

research and the schools gave permission for the testing to be conducted on their premises. The tasks were individually administered to all participants in quiet rooms in their schools. The tasks were administered in two sessions lasting up to 30 minutes each including an initial period of establishing rapport with the child through play. The tasks were administered in a fixed, predefined order: Counting recall task, Color-shape task, break, Nonverbal Stroop task, Backward digit span task and Local-global task. The Raven's Colored Progressive Matrices were always administered first in order to exclude children who perform below the 25th or above the 90th percentile: no children had to be excluded on the basis of this criterion. The break between sessions was no longer than three days and short breaks were also taken between each pair of consecutive tasks, in order to ensure that the children were rested and motivated to participate in the research.

Data processing

Response accuracy was recorded for all tasks, and for shifting and inhibition tasks reaction times (RTs) were recorded as well. All RTs shorter than 200ms and RTs for incorrect trials were excluded from the analysis. Furthermore, the data was trimmed both between and within subjects, so that values more than ± 3 SDs away from the (average and each participant's) mean RT were replaced by the ± 3 SD values. On both shifting tasks, the general shifting costs, used by Miyake et al. (2000), were calculated as differential reaction times by subtracting the average RT for the third block from the average RTs for the first two blocks taken together. Local shifting costs were calculated by subtracting the average RTs for the shift trials in the third block from the average RTs for non-shift trials within the same block. For both general and local shifting costs, values are expressed as negative numbers, such that higher values correspond to better shifting ability. In the nonverbal Stroop task the

inhibition cost was calculated as the difference between average RTs for congruent and incongruent stimuli. Higher scores indicated better inhibition.

Results

Table 2 shows the groups' performance on executive function tasks and the significance of group differences tested by a series of analyses of covariance with age and intelligence as covariates. ANCOVAs were chosen over a MANCOVA as some of the dependent variables correlated highly amongst themselves (e.g. backward digit span and score correlate $r = .92, p < .01$), making the data unsuitable for MANCOVA. Age was not a significant covariate for any of the tasks, while intelligence was significantly related to performance on the local-global task. The differences between the groups emerged on both working memory tasks. LSD pairwise group comparisons revealed that the children in the high exposure group significantly outperformed the control group, $D = 2.22, p < .05; D = .72, p < .05; D = 2.21, p < .01$ and $D = .69, p < .01$, for counting recall score, counting recall span, backward digit score and backward digit span, respectively. By contrast, the non-intensive exposure group's scores were between the HEG and the LEG scores and did not differ significantly from either the HEG or the CG scores.

A marginal main effect of group was found in the local shift cost of the color-shape task. LSD pairwise group comparisons revealed that the CG significantly outperformed the HEG, $D = 95.03, p < .05$. The LEG did not differ significantly from the other two groups. However, this result was not replicated on the other shifting task (the local-global task).

On the Stroop task, no group difference was found for the inhibition cost as measured by the differential RTs between the congruent and the incongruent conditions (Table 2). Surprisingly, however, a main effect of group emerged for the Stroop task overall RT, in that

the CG was significantly faster on this task (668ms for congruent and 874ms for incongruent trials) than the HEG, $D = -210.02, p < .05$ (811ms for congruent and 1102ms for incongruent trials), while the LEG did not differ significantly from either group (706ms and 1003ms for congruent and incongruent trials). Although overall RT for the Stroop task is not a measure of inhibition *per se*, but rather an aspect of cognitive speed, when viewed in combination with the differential RT it can potentially shed additional light on participants' performance on this task. It appears that the Stroop task was comparatively more difficult for the HEG than the CG; however, this did not lead to differential slowing down on the task, resulting in a lack of difference in inhibition performance.

Table 2

Results of ANCOVAs for executive function task scores with group means and standard deviations

Task	CG		LEG		HEG		Age			Intelligence			Group		
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>F</i>	<i>p</i>	η^2	<i>F</i>	<i>p</i>	η^2	<i>F</i>	<i>p</i>	η^2
Counting recall score	12.3	2.9	12.7	2.8	14.7	2.7	.7	.4	.01	3.6	.06	.06	3.8	.03	.13
Counting recall span	3.9	0.9	4.4	0.9	4.7	0.9	.5	.5	.01	1.9	.2	.03	3.4	.04	.11
Backward digit score	7.3	2.3	8.4	2.1	9.4	2.8	3	.1	.05	.1	.8	.00	4.2	.02	.14
Backward digit span	3.1	0.8	3.4	0.6	3.7	0.7	.5	.5	.01	.1	.8	.00	4	.02	.13
Nonverbal Stroop differential RT (ms)	-205.9	33.1	-308	38.8	-291.6	35.6	.5	.5	.01	.2	.7	.00	2.1	.13	.08
Color-shape general cost (ms)	-296.7	164.9	-354.8	274	-335.2	167.4	2.2	.2	.04	.01	.9	.00	.3	.8	.01
Color-shape local cost (ms)	-98	127.8	-169.8	97.6	-192.9	134	1.2	.3	.02	.3	.6	.01	3	.06	.11
Local-global general cost (ms)	-174.1	178.5	-201.4	164.5	-190.3	144.8	.1	.8	.00	6.1	.02	.10	.03	.9	.01
Local-global local cost (ms)	-103.7	158.8	-115.1	93.7	-168.9	105.6	3.3	.1	.06	5.7	.02	.10	.5	.6	.02

Discussion

Previous studies investigating the interplay between EF and dual language development of bilingual children attending second language education programs have shown that the length of second language exposure plays an important role. Nicolay and Poncelet (2013) reported positive effects of a three-year immersion program on tasks assessing alerting, auditory selective attention, divided attention and mental flexibility, thus suggesting that three years of second-language immersion school experience produces some of the EF benefits associated with early bilingualism. On the other hand, Carlson and Meltzoff (2008) demonstrated a bilingual advantage on a wide range of EF measures, but no such evidence was found for a six month second-language exposure program, suggesting that six months of intensive second language acquisition is not enough to affect executive control.

In order to expand our understanding of effects of second language exposure on EF, we set up two hypotheses: firstly, that one year is long enough to yield an advantage in executive functions for children immersed in a second language, and secondly, that the amount of exposure to the second language contributes to the size of this advantage. In our study we analyzed three components of executive functions as described by Miyake et al. (2000) – WM, inhibition and shifting.

Our first prediction, that one year in an immersive second language program is enough to affect the outcomes of tasks tapping EF in children, irrespective of the amount of exposure, was not supported by our data. No significant EF differences were found between the low exposure group of children and the monolingual group, suggesting that this length of exposure is not necessarily sufficient to yield an advantage on executive function tasks.

However, the data obtained in our study confirmed our second hypothesis by demonstrating an effect of the daily amount of exposure within a second-language immersion program on WM. The high exposure group outperformed the monolingual group on both complex WM tasks, while the low exposure group performed at a level between the HEG and CG and did not differ significantly from either. This finding cannot be explained by the influence of confounding variables, such as environment (children in all three groups came from monolingual homes in similar communities), intellectual abilities and socioeconomic background (which were comparable across groups). Under the assumption that the amount of exposure to a second-language immersion program affects EF, the observed difference between the HEG and the CG suggests that children with a higher amount of exposure to the second language get more practice in WM performance as a consequence of their continuous monitoring of the vocabulary and syntactic structures of the language in use as well as their continuous storing and updating of this information, leading to their advantage in WM ability. Our finding is in line with previous studies showing an advantage for five- to seven-year-old bilingual children on both verbal and visuospatial WM as compared to monolinguals (Blom et al., 2014; Bialystok, 2010; Morales et al., 2013).

According to our data, five hours of daily exposure to a second language for one year within an immersion program affects WM performance, but not shifting and inhibition. More precisely, in the case of inhibition the results were somewhat unexpected: the groups differed in overall reaction time on the Stroop task, but not on differential RT, which is the primary measure of inhibition. Overall RT could be interpreted as either a consequence of general cognitive speed or rather as an indicator of task difficulty for different groups (Hilchey & Kline, 2011). Our results would thus imply that the Stroop task was comparably the most

challenging for the HEG group; however, this group did not show weaker inhibition performance than the other two.

On the shifting task, we found a control group advantage that approached significance. This result, however, needs to be interpreted with caution for the following reasons. Firstly, the group differences were reaching significance on one of the shifting tasks, but not on the other, which employed the same methodology. In order to provide a better insight into potential disadvantages of learning a second language on shifting ability, at least in some stages of language acquisition, future studies should employ a larger number of diverse shifting tasks. Secondly, the sample size of the groups in the present study was relatively small, and hence no strong claims can be made on the basis of these equivocal results.

Our demonstration of a differential effect of the amount of daily exposure to a second language on the development of EF – that is, the presence of an effect on WM but not on other EF components, in this case shifting and inhibition – should inform theoretical models of executive functions by distinguishing among different component processes and by highlighting their importance for the activity which is controlled. Huizinga et al. (2006) have suggested that various EF components may develop asynchronously. It is likely that in the initial period of intensive second language acquisition, the processes of forming basic vocabulary and syntactic structures in the second language primarily engage WM. This would be similar to the processes described in monolingual acquisition, where WM abilities are strongly related to the rate of language acquisition and efficiency of processing (Gathercole & Baddeley, 1990; Montgomery, 2003; Majerus et al., 2006). Consequently, WM may be the most important component during the initial period of second language

acquisition. As Bialystok and Barac (2012) note, “(cognitive) control is sensitive to accumulating experience; executive control tasks rely on domain-general systems that are also recruited in bilingual language processing, but it takes time for these systems to reach sufficient levels to influence non-linguistic domains”.

In line with this, Costa et al. (2009) have argued that the nature of bilingual experience impacts on the development of different EF components. The authors proposed that in an environment where the two languages are mostly used in different contexts, bilingual speakers may not show advantages in cognitive control mechanisms. In the present study, the children attending the high exposure second-language immersion program for a period of one year are in a sociolinguistic environment in which the second language is used to a certain extent and in certain contexts at school. In this case, the use of the two languages is confined to clearly separated contexts, and as such the need to inhibit one language or switch between the two languages is rather limited. As a consequence, cognitive control mechanisms, such as inhibition and shifting, might not be engaged to a sufficient degree to reach those levels which would influence non-linguistic domains.

Our results showed that one year of immersion in a second language learning program is not automatically sufficient to yield an effect on executive functions, even in the case of WM. The effect seems to be influenced by the *amount of exposure*. According to the results from our study, there is little evidence for a selective advantage of the low exposure early immersion school program on selected measures of executive functions. With age and overall intelligence controlled, after a period of one year of second language instruction, the low exposure group performed similarly to the monolingual group on tasks assessing WM. The

dissociation between the two exposure groups indicates that the amount of exposure has to be taken into account.

Green and Abutalebi (2013) proposed the adaptive control hypothesis, according to which “language control processes themselves adapt to the recurrent demands placed on them by the interactional context”. This adaptation may concern the processes’ own neural instantiation or their functional relationship to other control processes. On this view, increasing second language proficiency calls for the speaker to adapt the processes that control interference. Specifically, “[i]nteractional cost imposes a demand to adapt the control processes of goal maintenance, conflict monitoring, and interference suppression” (Green & Abutalebi, 2013). This claim is supported by neuroimaging studies demonstrating that bilingualism changes the brain so as to make it more efficient in particular contexts (Della Rosa, Videsott, Borsa, Canini, Weeks, Franceschin, & Abutalebi, 2013). Alternatively, it could be that the level of language proficiency is the bridge between the amount of bilingual exposure and executive functions: that is, that the participants exposed to the intensive program have significantly increased their language proficiency, which in turn produced a benefit on tasks that involve WM ability. From this point of view, both the level of proficiency and the amount of exposure, provided they are balanced in the language environment, lead to better executive control skills (Luo, Luk, & Bialystok, 2010; Yow & Li, 2015).

In line with this, our data suggest that the initial period of intensive second language acquisition engages verbal WM and consequently general WM, in a way quite similar to WM engagement during the period of early language acquisition in monolinguals (Gathercole & Baddeley, 1990; Montgomery, 2003; Majerus et al., 2006).

Limitations of the study

Due to practical considerations (namely, the characteristics of the educational system in Serbia and availability of schools providing intensive education in the second language), children belonging to different experimental groups were recruited from different schools. Although it would have been preferable if children came from the same schools, we do not believe this to have had a significant impact on our results. All the schools that were included in the research are located in central parts of the city, the children attending them come from middle class families and the majority of their parents have completed university education, as reported by headteachers. Although it was not possible to match SES information provided by the headteachers to each participant individually, which would have allowed us to enter SES as a covariate in the statistical analysis, the three groups did not differ in this respect. Hence, the obtained group differences cannot be attributed to this factor.

Additionally, in the present study the children from the different schools were learning different languages. Although this is less than optimal, as it is possible that linguistic specificities of these languages have a differential influence on the development of executive functions, all L2s were Indo-European languages. Future studies might provide more definitive answers to the question of how typological factors bear upon the influence of language learning on EF.

Future research in this area should also attempt to shed more light on the relationship between amount of exposure and length of *experience* with the second language and their joint effect on cognitive control in a bilingual setting. In the present study, a benefit was obtained in the domain of WM. However, the rather small sample size of this study is one of its limitations. Nevertheless, our findings extend previous research demonstrating that daily

length of exposure is a significant factor affecting executive control in early second language acquisition immersion programs. Future research could explore when the bilingual advantage in other areas of EF emerges in bilingual children with intensive immersion education.

Conclusions

This study investigated whether child second language learners who attend two language immersion programs with different amounts of L2 exposure differ from their monolingual peers who attend mainstream monolingual schools, with respect to a range of executive function tasks including working memory, inhibition and shifting. This study showed that differences between the high exposure group and the monolingual control group emerged only in the area of working memory but not for other executive functions. These results help us understand the role of working memory in the early stages of intensive second language learning, and how it compares to other executive functions that have been shown to be affected by bilingual exposure, such as inhibition and shifting.

Acknowledgement

This research is the product of a short-term scientific mission within COST Action IS0804 “Language Impairment in a Multilingual Society: Linguistic Patterns and the Road to Assessment”, and was supported by the Ministry of Education, Science and Technological Development of the Republic of Serbia (projects 175012 and 179018).

Bangor University also supported this research by enabling the short-term scientific mission to take place and some of the tasks used in the research to be created.

We would like to thank the Deutsche Schule Belgrad, the British International School, Belgrade and the “Vladislav Ribnikar” elementary schools, and especially Oliver Repp, Neil Howie and Lidija Maksić for their generous support in recruiting participants for the study.

We also thank the students of the Psychology Department, Faculty of Philosophy, Belgrade University who helped in the data collection phase, particularly Olga Nedović.

The authors would like to thank the University of Luxembourg and Pascale Engel de Abreu for their generous hospitality during a previous short-term scientific mission.

References

- Alloway, T. P. (2007). *Automated Working Memory Assessment*. London: Harcourt Assessment.
- Antón E., Duñabeitia J. A., Estévez A., Hernández, J. A., Castillo, A., Fuentes, L. J., Douglas J. D., & Carreiraset, M. (2014). Is there a bilingual advantage in the ANT task? Evidence from children. *Frontiers in Psychology, 5*: 398.
- Archibald, L. M. D., & Gathercole, S. E. (2006). Nonword repetition: a comparison of tests. *Journal of Speech, Language, and Hearing Research, 49*, 970–983.
- Baddeley, A. D. (1998). The central executive: A concept and some misconceptions. *Journal of the International Neuropsychological Society, 4*, 523–526.
- Baddeley, A.D., Gathercole, S.E., & Papagno, C. (1998). The phonological loop as a language learning device. *Psychological Review, 105*, 158–173.
- Baddeley, A. D. (2000). The episodic buffer: A new component of working memory? *Trends in Cognitive Sciences, 4*(11), 417–423.
- Bialystok, E. (2001). *Bilingualism in Development: Language, Literacy, and Cognition*. New York: Cambridge University Press.
- Bialystok, E. (2010). Global-local and trail-making tasks by monolingual and bilingual children: Beyond inhibition. *Developmental Psychology, 46*, 93–105.
- Bialystok, E. (2011). Reshaping the mind: the benefits of bilingualism. *Canadian Journal of Experimental Psychology, 65*(2), 229–235.
- Bialystok, E., & Barac, R. (2012). Emerging bilingualism: Dissociating advantages for metalinguistic awareness and executive control. *Cognition, 122*, 67–73.

- Bialystok, E., Barac, R., Blaye, A., & Poulin-Dubois, D. (2010). Word mapping and executive functioning in young monolingual and bilingual children. *Journal of Cognition and Development: Official Journal of the Cognitive Development Society*, 11(4), 485–508. <http://doi.org/10.1080/15248372.2010.516420>
- Bialystok, E., & Feng, X. (2009). Language proficiency and executive control in proactive interference: Evidence from monolingual and bilingual children and adults. *Brain and Language*, 109(2-3), 93–100.
- Bialystok, E., Craik, F. I. M., Klein, R. & Viswanathan, M. (2004). Bilingualism, aging, and cognitive control: Evidence from the Simon task. *Psychology & Aging*, 19, 290–303.
- Bialystok, E., Peets, K., & Moreno, S. (2014). Producing bilinguals through immersion education: Development of metalinguistic awareness. *Applied Psycholinguistics*, 35, 177–191.
- Blom, E., Küntay, A. C., Messer, M., Verhagen, J. & Leseman, P. (2014). The benefits of being bilingual: Working memory in bilingual Turkish-Dutch Children. *Journal of Experimental Child Psychology*, 128, 105–119.
- Cain, K., Oakhill, J., & Bryant, P. (2004). Children's reading comprehension ability: Concurrent prediction by working memory, verbal ability, and component skills. *Journal of Educational Psychology*, 96(1), 31–42.
- Carlson, S. M. & Meltzoff, A. N. (2008). Bilingual experience and executive functioning in young children. *Developmental Science*, 11, 282–298.
- Costa, A., Hernández, M., Costa-Faidella, J., & Sebastián-Gallés, N. (2009). On the bilingual advantage in conflict processing: Now you see it, now you don't. *Cognition*, 113, 135–149.

- Cowan, N., Elliott, E. M., Sauls, J. S., Morey, C. C., Mattox, S., Hismjatullina, A., et al. (2005). On the capacity of attention: Its estimation and its role in working memory and cognitive aptitudes. *Cognitive Psychology*, *51*(1), 42–100.
- Daneman, M. & Carpenter, P. A. (1980). Individual differences in working memory and reading. *Journal of Verbal Learning & Verbal Behavior*, *19*, 450–466.
- Duñabeitia, J. A., Hernández, J. A., Antón, E., Macizo, P., Estévez, A., Fuentes, L. J., et al. (2014). The inhibitory advantage in bilingual children revisited. *Experimental Psychology*, *61*, 234–251.
- Della Rosa, P. A., Videsott, G., Borsa, V. M., Canini, M., Weeks, B. S., Franceschin, R. & Abutalebi, J. (2013). A neural interactive location for multilingual talent. *Cortex*, *49*(2), 605–608.
- Engel de Abreu, P. M. J., Cruz-Santos, A., Tourinho, C.J., Martin, R., & Bialystok, E. (2012). Bilingualism enriches the poor: enhanced cognitive control in low-income minority children. *Psychological Science*, *23*(11), 1364–1371.
- Engel de Abreu, P. M. J., & Gathercole, S. E. (2012). Executive and phonological processes in second-language acquisition. *Journal of Educational Psychology*, *104*(4), 974–986.
- Engel de Abreu, P. M. J. (2011). Working memory in multilingual children: Is there a bilingual effect? *Memory*, *19* (5), 529–537.
- Engel, P. M. J. (2009). *Working memory and learning: A 3-year longitudinal study of children growing up in a multilingual environment*. University of York, York.
- Francis, W. S. (1999). Cognitive integration of language and memory in bilinguals: Semantic representation. *Psychological Bulletin*, *125*(2), 193–222.

- Gathercole, V. C. M., Thomas, E. M., Kennedy, I., Prys, C., Young, N., Vinas Guasch, N., et al. (2014). Does language dominance affect cognitive performance in bilinguals? Lifespan evidence from preschoolers through older adults on card sorting, Simon, and metalinguistic tasks. *Frontiers in Psychology, 5*:11.
- Gathercole, S. E., Alloway, T. P., Willis, C., & Adams, A. M. (2006). Working memory in children with reading disabilities. *Journal of Experimental Child Psychology, 93*(3), 265–281.
- Gathercole, S. E., Hitch, G. J., Service, E., & Martin, A. J. (1997). Phonological short-term memory and new word learning in children. *Developmental Psychology, 33*, 966–979.
- Gathercole, S. E., Service, E., Hitch, G. J., Adams, A.-M., & Martin, A. (1999). Phonological short-term memory and vocabulary development: Further evidence on the nature of the relationship. *Applied Cognitive Psychology, 13*, 65–77.
- Gathercole, S., & Baddeley, A. (1990). Phonological memory deficits in language disordered children: Is there a causal connection? *Journal of Memory and Language, 29*, 336–360.
- Green, D. W., & Abutalebi, J. (2013). Language control in bilinguals: The adaptive control hypothesis. *Journal of Cognitive Psychology, 25*, 515–530.
- Hernandez, M., Costa, A., & Humphreys, G. W. (2012). Escaping capture: Bilingualism modulates distraction from working memory. *Cognition, 122*, 37–50.
- Hilchey, M. D., & Klein, R. M. (2011). Are there bilingual advantages on nonlinguistic interference tasks? Implications for the plasticity of executive control processes. *Psychonomic Bulletin & Review, 18*(4), 625–658. <http://doi.org/10.3758/s13423-011-0116-7>

- Huizinga, M., Dolan, C. V., & Van der Molen, M. W. (2006). Age-related change in executive function: developmental trends and a Latent Variable Analysis. *Neuropsychologia*, *44*(11), 2017–2036.
- Iluz-Cohen, P., & Armon-Lotem, S. (2013). Language proficiency and executive control in bilingual children. *Bilingualism: Language and Cognition*, *16*(4), 884–899.
- Kroll, J. F., Bobb, S. C., Wodniecka, Z. (2006). Language selectivity is the exception, not the rule: arguments against a fixed locus of language selection in bilingual speech. *Bilingualism: Language and Cognition*, *9*, 119–135.
- Kroll, J. F., Dussias, P. E., Bice, K., & Perrotti, L. (in press). Bilingualism, mind, and brain. In M. Liberman & B. H. Partee (Eds.), *Annual Review of Linguistics*.
- Luk, G., de Sa, E., & Bialystok, E. (2011). Is there a relation between onset age of bilingualism and enhancement of cognitive control? *Bilingualism: Language and Cognition*, *14*, 488–495.
- Lukács, Á., Ladányi, E., Fazekas, K., & Kemény, F. (2015). Executive functions and the contribution of short-term memory span in children with specific language impairment. *Neuropsychology*, Advance online publication. <http://dx.doi.org/10.1037/neu0000232>
- Luo, L., Luk, G., & Bialystok E. (2010). Effect of language proficiency and executive control on verbal fluency performance in bilinguals. *Cognition*, *114*(1), 29–41.
- Majerus, S., Poncelet, M., Greffè, C., & van der Linden, M. (2006). Relations between vocabulary development and verbal short-term memory: The relative importance of short-term memory for serial order and item information. *Journal of Experimental Child Psychology*, *93*(2), 95–119.

- Marian, V., Spivey, M., & Hirsch, J. (2003). Shared and separate systems in bilingual language processing: Converging evidence from eyetracking and brain imaging. *Brain & Language, 86*(1), 70–82.
- Martin-Rhee, M. M., & Bialystok, E. (2008). The development of two types of inhibitory control in monolingual and bilingual children. *Bilingualism: Language and Cognition, 11*, 81–93.
- Masoura, E. V., & Gathercole, S. E. (2005). Contrasting contributions of phonological short-term memory and long-term knowledge to vocabulary learning in a foreign language. *Memory, 13*(3-4), 422–429.
- Miyake, A., Friedman, N. P., Emerson, M. J., Witzki, A. H., Howerter, A., & Wager, T. D. (2000). The unity and diversity of executive functions and their contributions to complex “Frontal Lobe” tasks: a latent variable analysis. *Cognitive Psychology, 41*(1), 49–100.
- Montgomery, J. (2003). Working memory and comprehension in children with specific language impairment: what we know so far. *Journal of Communication Disorders, 36*, 221–231.
- Morales, J., Calvo, A., & Bialystok, E. (2013). Working memory development in monolingual and bilingual children. *Journal of Experimental Child Psychology, 114*, 187–202.
- Nicolay, A. C., & Poncelet, M. (2013). Cognitive advantage in children enrolled in a second-language immersion elementary school program for three years. *Bilingualism: Language and Cognition, 16*, 597–607.

- Okanda M, Moriguchi, Y., & Itakura, S. (2010). Language and cognitive shifting: evidence from young monolingual and bilingual children. *Psychological Reports, 107(1)*, 68–78.
- Paap, K. R., & Greenberg, Z. I. (2013). There is no coherent evidence for a bilingual advantage in executive processing. *Cognitive Psychology, 66*, 232–258.
- Pelham, S. D., & Abrams, L. (2014). Cognitive advantages and disadvantages in early and late bilinguals. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 40*, 313–325.
- Poarch, G. J., & Van Hell, J. G. (2012). Executive functions and inhibitory control in multilingual children: Evidence from second language learners, bilinguals, and trilinguals. *Journal of Experimental Child Psychology, 113(4)*, 535–551.
- Poulin-Dubois, D., Blaye, A., Coutya, J., & Bialystok, E. (2011). The effects of bilingualism on toddlers' executive functioning. *Journal of Experimental Child Psychology, 108*, 567–579.
- Prior, A., & MacWhinney, B. (2010). A bilingual advantage in task switching. *Bilingualism: Language and Cognition, 13(2)*, 253–262.
- Raven, J. C., Court, J. H., & Raven, J. (1986). *Coloured Progressive Matrices*. London: H. K. Lewis.
- Rodriguez-Fornells, A., Rotte, M., Heinze, H. J., Nosselt, T. & Munte T. F. (2002). Brain potential and functional MRI: Evidence for how to handle two languages with one brain. *Nature, 415*, 1026–1029.
- Schneider, W., Eschmann, A., & Zuccolotto, A. (2002). *E-Prime User's Guide*. Pittsburgh: PA: Psychology Software Tools, Inc.

- Seigneuric, A., Ehrlich, M. F., Oakhill, J. V., & Yuill, N. M. (2000). Working memory resources and children's reading comprehension. *Reading and Writing, 13*, 81–103.
- Thierry, G., & Wu, Y. J. (2007). Brain potentials reveal unconscious translation during foreign-language comprehension. *PNAS, 104*(30), 12530–12535.
- Valian, V. (2015). Bilingualism and cognition. *Bilingualism: Language and Cognition, 18*, 3–24.
- Verhagen, J., Mulder, H., & Leseman, P. (2015). Effects of home language environment on inhibitory control in bilingual three-year-old children. *Bilingualism: Language and Cognition*. <http://doi.org/10.1017/S1366728915000590>
- Xie, Z. (2014). Second-language proficiency, Language use, and mental set shifting in cognitive control among unbalanced Chinese-English bilinguals. *SAGE Open*, October-December: 1–10, doi: 10.1177/2158244014563040
- Yow, W. Q., & Li, X. (2015). Balanced bilingualism and early age of second language acquisition as the underlying mechanisms of a bilingual executive control advantage: why variations in bilingual experiences matter. *Frontiers in Psychology, 6*:164.