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The Impact of Bilingualism on Verbal Fluency and Executive Functions: The Case of L2-immersed and Non-immersed Czech-English Bilinguals

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Prohlášení:

Prohlašuji, že jsem diplomovou práci vypracovala samostatně pod vedením Mgr. Šárky Šimáčkové, Ph.D. a že jsem použila pouze zdroje, které uvádím v seznamu literatury a zdrojů.

V Olomouci dne … 7. 5. 2020 …………….. Podpis: ……………………………………………

Poděkování:

Děkuji vedoucí práce, Mgr. Šárce Šimáčkové, Ph.D., za veškerou pomoc a věnovaný čas, za odborné vedení, cenné rady a podnětné připomínky v průběhu vzniku této práce. Ráda bych poděkovala mé mamince, která mi studium umožnila a podporovala mě. Děkuji mému příteli, celé rodině a přátelům za psychickou podporu, trpělivost a pochopení, především Maxíčkovi a Matýskovi. V neposlední řadě děkuji všem zúčastněným probandům.

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1 INTRODUCTION

As a result of all the recent advances and the process of globalization, monolingualism has become more of an aberration rather than the norm. In contrast to the shared misconception that bilingualism is unusual, it has been estimated that more than a half of the world's population possesses the ability to speak more than one language fluently (Bialystok et al., 2009). Therefore, there is a growing interest of scientists in investigating bilingual language processing and its cognitive bases.

Research dedicated to the study of consequences of bilingualism suggests that the regular use of two languages by bilingual individuals has a significant impact on linguistic and cognitive functioning. There is evidence that in the bilingual lexicon both languages receive a level of activation during comprehension and production (Kroll et al., 2008), which affects linguistic performance in L2 as well as L1. With two simultaneously active language systems, bilinguals are required to use cognitive control abilities to pay attention to the linguistic environment, select the appropriate language, inhibit the non-relevant one, and manage the lexical and grammatical within-language and between-language interference (Green, 1998). Cognitive control is therefore crucial in order to avoid the negative transfer, which would impede the process of understanding. The necessary and constant inhibition of the non-target language has been linked to changes in bilinguals' cognitive control mechanism. It is hypothesized that a bilingual cognitive advantage emerges from the increased lexical competition and greater demands posed on inhibition, monitoring, and switching between languages (Bialystok, 2001). Lately, studies have been concerned with determining whether or not bilingualism leads to benefits across a variety of different executive functions, such as inhibitory control, selective attention, mental-set shifting or working memory. Reported data propose that the more extensive experience with linguistic inhibition, the greater the cognitive benefits may be (Heildmayr et al., 2013).

Heidlmayr et al. (2013) and Coderre et al. (2013) report results highlighting sensitivity of the bilingual advantage to factors such as effects of language immersion. Sabourin and Vinerte (2014), Coderre et al. (2013) and Kroll et al. (2008) remark that immersion in the non-native language and its consequences for cognitive control provide an interesting avenue for investigation and prompt further research, since it has received little attention in the literature. They mention that living in a foreign country and hearing a non-native language every day may create a long-term and sustained language conflict, consequently boosting the bilingual advantage in immersion groups of participants. In other words, bilinguals immersed in their weaker language engage cognitive control to a greater extent on a daily basis due to the need to avoid interference from the dominant language, which would predict larger cognitive advantages for immersed bilinguals.

The present thesis aims at extending research in this area by examining the impact of the little-explored variable, immersion, on executive functions and efficiency of word retrieval by testing healthy sequential Czech-English bilinguals using, the Stroop task, the Verbal Fluency task and the Auditory Backward Digit Span test. Since the aim of the current thesis is to provide a greater insight into the relationship amongst L2-immersion and presumed executive control processes underpinning verbal fluency performance, following the methodology by Patra et al. (2019), we measured verbal fluency, inhibitory control and working memory. Our predictions were based on the bilingual cognitive advantage hypothesis, which stems from the theory of nonselective access to an integrated bilingual lexicon (Green, 1998), simultaneous activation of the target and the non-target language (Kroll et al., 2008), and the hypothesis that the constant exertion of control over the non-target language to avoid cross-language interference leads to an overall enhancement of executive control processes (Bialystok, 2001).

Concerning the structure of this thesis, the first chapter summarizes recent findings and hypotheses regarding language processing and lexical access of bilingual speakers as well as advantages and disadvantages induced by bilingualism. It further compares three non-selective models of bilingual language processing, which predict a different role for suppression mechanism. The chapter also includes a division of executive functions responsible for achieving and maintaining proficient bilingualism and discusses the factor of L2 immersion in language learning experience. The second chapter introduces the participant groups, describes procedures of the used experiments in detail, reports and analyses the collected data. The third chapter summarizes findings of this thesis and provides answers for the following research questions. Against the background described above, the current thesis addresses the following research questions:

1. What influence, if any, does immersion have on the cognitive control and verbal fluency of bilinguals?
2. Do immersed bilinguals have better cognitive control due to increased frequency of L2 use and greater demand on inhibitory control?

2 GENERAL INTRODUCTION

2. 1. Bilingual Advantages and Disadvantages

Recent studies have demonstrated the consequences of life-long bilingualism in both verbal and nonverbal tasks (for detailed review of this literature see Bialystok et al., 2009). Two patterns have emerged from this research: *disadvantages* in tasks assessing linguistic processing, such as rapid verbal production or picture naming (Costa, 2005) and *advantages* in tasks that rely heavily on executive control, such as conflict resolution or control of attention (Bialystok, 2007). Both effects are a consequence of the co-existence of two language systems in bilingual minds but reflect opposite outcomes of that situation. In other words, it may be simultaneously detrimental to linguistic performance but advantageous to cognitive ability. The aim of this chapter is to summarize recent findings and hypotheses concerning advantages and disadvantages of bilingualism. As emphasized by Coderre et al. (2013), these hypotheses point to different mechanisms being the critical factor in bilingual performance and therefore are not mutually exclusive.

Research concerned with differences between bilingual and monolingual speakers sheds light on some of the necessary cognitive mechanisms responsible for achieving and maintaining proficient bilingualism. Bilingual advantages and disadvantages in verbal tasks depend on both language proficiency in each language, notably vocabulary size, and level of executive control involved in the task. In tasks that have little role for executive control and rely primarily on lexical access, such as category fluency, bilingual disadvantages may disappear if monolinguals and bilinguals are matched on a measure of language proficiency such as vocabulary knowledge. In contrast, bilingual advantages may emerge on verbal tasks that demand higher levels of executive control, such as letter fluency, once relevant differences in language proficiency have been accounted for (Luo et al., 2010). Bialystok and her colleagues (2008) conclude that bilinguals, when performing lexical retrieval tasks, balance their deficits in vocabulary against their advantages in executive functioning.

2. 1. 1. Bilingual Disadvantage Hypotheses

Cognitively intact adult bilinguals who are highly proficient in both languages often reveal a deficit relative to monolinguals in tasks assessing aspects of linguistic processing as in picture naming (Marian et al., 2007; Gollan et al., 2007), lexical decision, or verbal fluency tasks (Bialystok et al., 2008). Further, bilinguals experience more tip-of-the-tongue retrieval failures than monolinguals when they are asked to produce very low-frequency words (Gollan & Acenas, 2004). Even balanced bilingual speakers exhibit a lexical access disadvantage in language production in their L1 in comparison with monolinguals (Boston Naming Test in Gollan et al., 2007; Costa & Ivanova, 2007). The latter argue that the effect could be interpreted as a "frequency effect in disguise", according to which bilinguals would need more time to retrieve lexical items from their L1 lexicon since they use these words less often than monolingual speakers. In addition to less efficient lexical retrieval usually signalled in slower naming latencies, research has provided evidence that bilinguals have smaller vocabularies in each language than their comparable monolingual counterparts (Portocarrero et al., 2007; Bialystok et al., 2008). These two disadvantages observed in bilinguals, namely, weaker lexical retrieval and lower vocabulary scores, may be related. Reported results by Luo et al. (2010) indicate a mediating role for vocabulary knowledge in bilingual performance on tasks of lexical access. The authors argue that the smaller vocabulary size is one of the factors underlying disadvantages demonstrated in longer naming latencies and a smaller number of words produced in Verbal Fluency tasks, for example. Additionally, Segalowitz & Hulstijn (2005) found that highly proficient bilinguals read more slowly in L2 than in L1 despite comparable oral facility in the two languages. They suggest that less automaticity of word recognition and orthographic processing causes reading in L2 to be more effortful.

Although the mechanism explaining the above-mentioned negative effects remains unclear, there are various explanations for this deficiency in lexical retrieval discussed in detail by Costa (2005), who tested possible processes which may account for the disadvantage: (1) reduced vocabulary size in each language (Portocarrero et al., 2007), (2) slower lexical retrieval due to interference between languages (Sandoval et al., 2010) and (3) reduced language-specific language use (weaker links) (Gollan et al., 2008). The cross-language interference hypothesis attributes the disadvantage to non-selective access to an integrated bilingual lexicon (Green, 1998), that is, the presence of two lexicons activated in parallel (Kroll et al., 2008) causing competition between potential lexical candidates and creating delays in lexical access. The weaker links hypothesis, also referred to as the reduced frequency hypothesis, approaches the disadvantage in terms of the frequency of language use. This theory suggests that compared to monolinguals, bilinguals use both languages less often, including their L1. Hence this reduced frequency of use leads to weaker links between words and concept and predicts delayed lexical access. By the same reasoning, this hypothesis further predicts slower lexical access in L2 compared to L1, which is supported by extensive evidence (Coderre et al., 2012).

2. 1. 2. The Bilingual Cognitive Advantage Hypothesis

One of the most remarkable abilities of bilingual speakers is being able place themselves in so called “monolingual mode” and select representations from the intended lexicon, while preventing massive interference from the non-response language. The bilingual cognitive advantage hypothesis, a phenomenon in the recent research of bilingualism, stems from the theory of nonselective access to an integrated bilingual lexicon (Green, 1998) and simultaneous activation of the target and the non-target language (Kroll et al., 2008) even in completely monolingual contexts. Under the premises of this approach, the two languages compete for selection as representations in both languages are activated, and the non-target language is suppressed by an inhibitory control mechanism in order to facilitate selection of the target language (TL). This advantage has been attributed to the enhancement of executive processes through their constant involvement in ordinary language use; bilingual language production involves a conflict between two competing language systems, the conflict carries costs in both time and accuracy, and the frontal cortex responsible for executive functioning is recruited to resolve this conflict (Bialystok et al., 2008). It proposes that the constant exertion of an effective control over the non-relevant language to avoid cross-language interference and production errors leads to an overall enhancement of executive control processes resulting in better performance (i.e. less interference) for bilinguals than monolinguals on conflict tasks, such as the Stroop task (Bialystok, 2001). This advantage is related to the very mechanism that produces the bilingual disadvantage in lexical access in bilingual speech performance discussed in the previous chapter.

Several authors like Bialystok (2001), Luo et al. (2010) or Coderre et al. (2012) argue that the advantage is not purely language-based, but benefits executive processing more generally and extends to other non-linguistic conflict tasks, such as the Flanker task, Simon task or Wisconsin Card Sorting task. Unlike the language-specific mechanism described by Sandoval et al. (2010), they propose that bilingual language experience enhances mechanism which resides in a domain-general set of cognitive processes responsible for executive functions, namely, selective attention, inhibitory control, working memory, monitoring, and cognitive flexibility. Branzi et al. (2016) investigated whether the bilingual language control (bLC) system utilizes various processes of the domain-general executive control (EC) system. Although other behavioral studies have provided evidence of a link between bilingual language processing and EC, the study failed to show a complete overlap between bLC and domain-general EC.

The notion that the long-term practice of managing two languages is beneficial for the executive control system is an ongoing debate. Reports of bilingual advantage in executive functioning inspired a global research effort of significant magnitude in the area of bilingualism research. It became one of the most newsworthy topics in cognitive psychology. In spite of extensive investigation, there is, however, no consensus regarding the existence of such bilingual advantage. Studies have reported divergent findings ranging from cognitive advantage for bilinguals to no differences between the groups. Criticism have been raised that studies demonstrating a bilingual advantage often suffer from small sample sizes. For example, despite a large study sample and various measures of inhibition (hereafter called suppression interchangeably) and switching, results reported by Sörman et al. (2019) did not support any beneficial effects related to improved processing costs in executive functioning. Analyses by Lehtonen et al. (2018) revealed very small bilingual advantage in inhibition, shifting, and working memory, but not for monitoring or attention. They conclude that the available evidence does not provide systematic support for the widely held notion that bilingualism is associated with benefits in cognitive control functions.

2. 2. Bilingual Language Processing

The existence of bilingualism offers a window through which the process of language production can be studied, particularly in relation to the speed of access of words, depending on which language (L1 or L2) is tapped. This chapter discusses three influential non-selective models of bilingual language processing, i.e. Inhibitory Control Model (IC; Green, 1998), Bilingual Interactive Activation model (BIA+; Dijkstra & Van Heuven, 2002) and Revised Hierarchical Model (RHM; Kroll & Stewart, 1994). As Dijkstra (2005) describes, non-selective access necessitates a highly effective mechanism of control over the non-relevant language to avoid cross-language comprehension or production errors. It allows competition for selection such that candidates within and across languages actively compete with alternatives in the unintended language, which are eventually inhibited to allow accurate production to proceed. This dual activation is supported by recent research on the organization of two languages in the mind of adult bilinguals that convincingly shows that both languages remain active to some degree during language processing in either language (Kroll et al., 2008), thus recruiting mental processes to control the relative level of activation, especially inhibition. Without procedures for separating the languages, any use of one language would evoke unwanted intrusions from the other. This view is in contrast with earlier models that proposed a "switch" that activated only the target language (selective access). When bilinguals are successful at suppressing the non-TL, they would be expected to perform language tasks similarly to their monolingual counterparts. However, the models support the view that bilinguals can never completely "shut off" the non-target language and be functionally monolingual, since the presence of the L2 changes the configuration of the language system, including processing of L1.

The nature of bilingual disadvantages and cognitive advantages can be used to constrain models of bilingual language processing and to highlight aspects of cognitive processing that are critical for achieving and maintaining proficient bilingualism. The reviewed models provide mechanisms for linking inhibition to bilingual processing. As already discussed, despite the obvious benefits of restricting activation to one language, the language non-specific models of bilingual speech production postulate that conceptual representations spread activation to the lexical representations of both languages of a bilingual. The extent to which the bilingual cognitive system is flexible enough to modulate the activation of the two lexicons of a bilingual during speech production is an open question that requires further research (Dijkstra, 2005).

2. 2. 1. The Inhibitory Control Model

One of the models that assigns a crucial role to inhibition of competing lexical representations is Green's (1998) Inhibitory Control Model. According to the IC Model, the language control process is executed via multiple levels of control. Unlike in monolingual processing, bilingual processing requires suppression at a higher-order level of attentional control being exerted both on linguistic and non-linguistic domains (Heidlmayr et al., 2013). Following this assumption, the IC model can account for bilingual advantages either in tasks involving a linguistic component (e.g. Stroop task) or not (e.g. Simon task). Green (1998) follows Levelt et al. (1999) in assuming multiple level of activation, but unlike Levelt et al.'s model, the IC model asserts that lemmas are tagged with a particular language, L1 or L2. The IC model posits that cross-language interference is resolved by applying inhibition to the non-target language that is proportional to its strength (level of activation); that is, the stronger the language, the more the inhibition needs to be applied. Hence, the dominant language (i.e., the L1) is more inhibited than the weaker language (i.e., the L2 and the L3). Therefore, suppression of L1 words is predicted to be more difficult than suppression of L2 words because L1 typically has a higher resting level of activation than L2 as it has been used much more often by the bilinguals than L2 in the course of their lifetime. The counterintuitive asymmetrical pattern of switch costs and the difference in resting activation of the L1 and L2 in unbalanced bilinguals is supposed to be due to differences in frequency of use (i.e. activation) and as well as to language dominance.

2. 2. 2. The Bilingual Interactive Activation+ Model

An alternative psycholinguistic model on bilingual language control is the Bilingual Interactive Activation+ model (Dijkstra & Van Heuven, 2002). Like the IC model (Green, 1998), the BIA+ model postulates an initial co-activation of both languages in bilingual individuals. In this paradigm, the automatic inhibition in language selection is specific to the language domain only. In contrast to the IC model, the BIA+ model can only account for advantages in tasks involving a linguistic component. Therefore, a crucial difference between the IC model and the BIA+ model lies in the localisation of the levels of control on language selection and inhibition. Language selection in the BIA+ mainly relies on differences between activation levels of L1 and L2. Dijkstra and Van Heuven (2002) point out that the more frequently a certain word is used, the faster it is believed to be activated. Therefore, the activation of a word in the L1 should be faster than the activation of a word in the L2, because the L1 word is used more frequently than the L2 word (Fidler & Lochtman, 2019). The degree to which there is sustained activity of the nontarget language depends on a variety of factors, including the language of production (L1 or L2), proficiency in the L2, the task that initiates speech planning, and the degree to which specific lexical alternatives are primed (Kroll et al., 2008). According to the IC Model and BIA+: (1) as mentioned, L1 has generally a higher resting level of activation compared to L2, and (2) stimuli words provide external cues that continuously boost the activation of the lexicon (Dijkstra, 2005).

2. 2. 3. The Revised Hierarchical Model

The RHM of bilingual language processing leads to similar predictions, although it proposes that the inhibitory control plays a less-direct role in proficient bilingualism. Because L1 is the dominant language, strong bidirectional links also exist between L1 words and concepts at all stages of L2 proficiency. In contrast, lexical links from L1 to L2 and bidirectional links between L2 words and concepts are initially weak and only become stronger with increasing proficiency, which is a difficult process likely to be influenced by individual differences in cognitive skills. Kroll and Stewart (1994) agree that concept activation is easier for L1 words than for L2 words.

In comparison, the IC Model predicts that bilinguals must be able to efficiently suppress the activation of L1 words to produce words in L2 at all level of proficiency. On the other hand, the RHM suggests that suppression should be especially important for less-proficient bilinguals. The two models do not necessarily contradict each other, but instead highlight different roles for suppression at various stages of bilingual processing (Dijkstra, 2005).

2. 3. Executive Functions

Executive functions, collectively referred to as cognitive control, are a set of higher-level cognitive processes that are necessary to control and coordinate other cognitive abilities and behaviours. Executive functions, especially cognitive inhibition, play an essential role in the language control process. Like other psychological constructs, executive function is multidimensional. Several models provide different viewpoints of the basic component processes associated with executive functions. Among them, the model of Miyake et al. (2002) used in Patra et al. (2019) postulates a division into the three most discussed executive functions controlled by the frontal lobe, namely (1) inhibition of dominant responses (i.e. the ability to inhibit dominant, automatic, or prepotent responses), (2) shifting of mental sets (i.e. the ability to flexibly switch back and forth between tasks or mental sets), and (3) updating working memory representations (i.e. the ability to monitor and update information). These three EFs are diverse, but tightly interrelated and overlapping.

2. 4. Second Language Immersion Experience

As Bialystok and her colleagues (2009) emphasize, bilingual individuals vary enormously in their language skills. A few of the many factors that affect the degree of language proficiency of bilinguals are age and manner of acquisition of each language, degree of use of each language over a lifetime, or level of formal education in each language. It seems likely that these same factors also affect the extent to which bilingualism modifies cognitive functions.

Based on the assumption that cortical organization is plastic and that it can be altered with experience, bilingualism and its constant negotiation of two languages, switching attention between them and choosing the correct response-language, provides a range of cognitive activities resulting in structural changes of the brain. With regards to immersion experience, besides the effects of L2-immersion described in the following chapters, reported results by Pliatsikas et al. (2017) show that significant subcortical reshaping in sequential bilinguals is directly related to the amount of conscious L2 usage, or L2 immersion. Some of the structural (palladial and thalamic) effects implicated in cognitive control positively correlated with extensive L2-immersion experience. Importantly, none of these effects emerged in a group of bilinguals with limited immersion experience, comparable L2 proficiency and age of acquisition (AoA). They conclude that structural effects pertinent to simultaneous bilinguals, as well as the cognitive effects they may convey, are applicable to late bilinguals as well.

With the exception of a handful of studies, the role of immersion and executive control during language production amongst bilinguals has not been reported. Therefore, the goal of our experiments was to investigate whether L2-immersion experience influences performance of a homogenous sample of Czech-English sequential bilingual speakers on conflict resolution and rapid word retrieval in their L1 and L2. Concerning the chosen experiments, they are designed to tap into multiple cognitive functions. Hence interpreting the experiments and comparing the groups required breaking down each task into individual components and then generating different predictions regarding how each component should or should not be affected by L2 immersion.

3 MEASURES AND EXPERIMENTS

Following the methodology by Patra et al. (2019), we employed LexTALE to measure vocabulary size, the Stroop task to measure selective inhibition, the Verbal Fluency task to measure verbal fluency, and the Auditory Backward Digit Span test to measure working memory. This chapter begins with the introduction of the participant groups and proceeds with description of the applied measures and conducted experiments. The second subchapter 3.2. deals with contribution of proficiency to VF performance and includes LexTALE vocabulary size assessment of the participants. The following three experiments investigate executive functions of the immersed and non-immersed bilinguals. In the subchapter 3.3., we describe the BDS test and review some of the literature linking working memory to language processing, attempting to elucidate the relationship between working memory capacity and bilingual VF performance. The next subchapter is focused on the impact of immersion on the performance of a rapid retrieval task, i.e. oral Verbal Fluency task, and its connection to cognitive abilities. The subchapter 3.5. is concerned with the Stroop task and the role of inhibition in bilingual language processing and production. Finally, bringing the strands of testing together, the last subchapter discusses the collected data.

3. 1. Participants

There were two groups in this study: immersed (n = 12; 10 females) and non-immersed (n = 9; 8 females) Czech-English successive unbalanced and healthy bilinguals. These participants voluntarily participated in the present research and did not receive any financial compensation. Participants were included in the immersed group if they met the following criteria: (a) they were 23‑33 years old (M = 28.67, SD = 2.57), (b) they were born in the Czech Republic, (c) Czech was their native/ first language (L1), (d) English was their second language (L2), (e) they rated themselves as highly-proficient bilinguals (C1 level according to CEFR), (f) they have acquired university education, (g) they have lived in an anglophone country (Canada) for at least the past half a year (M = 3.86, SD = 2.84), (h) they used English more frequently than Czech on a daily basis. Participants were included in the non-immersed group if they met the following criteria: (a) they were 23‑33 years old (M = 25.22, SD = 1.48), (b) they were born in the Czech Republic, (c) Czech was their native/ first language (L1), (d) English was their second language (L2), (e) they rated themselves as highly-proficient bilinguals (C1 level according to CEFR), (f) they have acquired university education, (g) they have not lived in an English speaking country for longer than 1 month, (h) they used Czech more frequently than English in their daily life. The two groups were matched for age, language combination, age of acquisition (AoA), language dominance, level of education and the self-rated proficiency in L2 (see Table 1 below). All participants were right-handed, with normal or corrected vision, no history of hearing impairment, and no history of any neurological illness. The efficiency of executive functions has been shown to vary significantly with age and IQ (Heidlmayr et al., 2013). Due to the lack of a free, valid and efficient IQ test, we included only university educated participants, assuming a necessary amount of intelligence required to achieve such an academic level. Both groups of participants included individuals with bachelor's and master's degree education. Although it is difficult to obtain a comprehensive assessment of all relevant factors in each individual case, yet such assessment is necessary to interpret bilingual performance accurately. The advantage of including a homogenous sample was that confounding variables which could play a role in assessing bilingual executive functions and VF were controlled, which we hoped would decrease the within-group variability and findings could be attributed to the examined processes.

As bilingualism can be defined in different ways, according to the approach taken in this thesis, bilingualism emerges when a speaker is able to reproduce meaningful utterances in another language. Since perfectly balanced knowledge of both languages is rare, the recruited subjects are unbalanced bilingual speakers, who have a dominant and more proficient language, which is their native language (i.e. Czech). All participants, whose home language was the majority language, started learning English before the onset of adolescence in a formal setting. Given their early monolingualism and maintenance of a largely L1 immersive environment even after the onset of L2 study, they are less likely to suffer from frequency effects in their L1 exposure and use, and are likely to have monolingual-like L1 vocabulary knowledge (Mathison, 2017). Nonetheless, the situation changes with L2-immersion. All immersed individuals moved to the L2-environment (i.e. Canada) in adulthood at the mean age of 24.41 years (SD = 1.83).

The immersed group was recruited in Vancouver, Canada, the non-immersed group in Olomouc, Czechia. The non-immersed participants were current or former university students of English literature and linguistics. All participants were tested individually in their L1 (Czech) and L2 (English). Data was collected during two test sessions on two different days at least one week apart in order to reduce practice effects. The sessions were counterbalanced for order of presentation, that is, one half of each group completed testing first in Czech, the other half in English. The L1 session included the following tasks in fixed order: Stroop Task, Verbal Fluency Task, Auditory Backward Digit Span Test. The L2 session included the following tasks in the fixed order: LexTALE, Stroop Task, Verbal Fluency Task. The two test sessions lasted approximately 1 hour per each participant.

Table 1. Participant groups

Group	*n*	Age (years)	AoA (years)	AoI (years)	English Proficiency (% in LexTALE)	Self-rated English Proficiency (/10)	Daily use of English (%)
Immersed	12	28.67	8.58	24.41	76.46	8.48	71.67
Non-immersed	9	25.22	8.44	n/a	85.83	8.61	29.89

3. 1. 1. Language Experience and Proficiency Questionnaire

Each participant gave written consent to participate in the present research and filled out an adapted Czech version of the Language Experience and Proficiency Questionnaire (LEAP-Q) created by Marian, Blumenfelf and Kaushanskaya (2007) (see Appendix A). The authors' aim was to develop a reliable and valid questionnaire capturing factors that have been previously identified as important contributors to efficient assessment of bilinguals' linguistic profiles: language dominance, language proficiency, onset of bilingualism, modes of language acquisition, and current language use. The questionnaire yielded self-reported ratings of language proficiency in speaking, comprehension, reading, and writing, as well as participants' age of immersion in the L2-speaking country (AoI), duration of the L2 immersion, and frequency of use of L1 and L2. Participants' self-reported L2 language history and proficiency measures can be found in Table 1 and 2. Participants completed the questionnaire independently in approximately 15 minutes. When asked what different factors contributed to their L2 learning besides formal education, they replied that it mostly relied on interaction with friends, followed by travelling, reading and self-teaching. Most participants reported proficient knowledge of other languages, such as German, French, Italian, Spanish or Slovakian, but their proficiency levels did not surpass the one of English. A few studies focused on whether the regular use of an additional third language might reinforce the effects of bilingualism. Data by Heidlmayr et al. (2013) highlighted that bilinguals with an additional L3 appear to have a higher capacity for inhibiting interferences in cases of conflicts between competing information.

Table 2. Participants' self-reported language history and proficiency

Language history measures	Immersed		Non-immersed	
	M	*SD*	*M*	*SD*
Self-reported proficiency (/10)	**8.48**	0.32	**8.53**	0.32
Comprehension	8.83	0.58	8.89	0.60
Speaking	8.25	0.75	8.56	1.13
Writing	8.17	0.83	8.11	0.60
Reading	8.67	0.98	8.56	0.53
AoA (years)	**8.58**	2.50	**8.44**	1.67
AoI (years)	24.42	1.83	n/a	n/a
Immersion duration (years)	3.86	2.84	n/a	n/a

3. 2. LexTALE

Within the field of verbal fluency, the focus of the present study, proficiency has been found to be positively related to performance in VF (Hedden et al., 2005) and vocabulary size has been found to account for a large portion of variance in performance on lexical tasks as well (Bialystok et al., 2008). Costa & Santesteban (2004a) argue that the control mechanism that guarantees lexical selection in the target language crucially depends on the L2 proficiency. Luo et al.'s (2010) results indicate that language proficiency as indicated by vocabulary size plays a critical role in whether bilingual differences in letter fluency are predominantly driven by language interference (as in the case of low-vocabulary bilingual speakers) or by superior executive control (as in the case of high-vocabulary bilinguals). Due to the importance of assessing these two variables when interpreting bilingual effects on lexical retrieval, the present study included Lexical Test for Advanced Learners of English, i.e. LexTALE, designed by Lemhöfer and Broersma (2011). This yes/ no polar test was created as a reaction to the common problem arising in L2 research, the lack of a feasible and objective measurement instrument of English vocabulary knowledge and proficiency. Most bilingual studies in psycholinguistics rely on participants' subjective self-rated scores as the only measure of proficiency. Concerning LexTALE's reliability, results reported by Lemhöfer and Broersma (2011) show LexTALE as a valid indicator of

English vocabulary knowledge and a good predictor of general English proficiency for medium to highly proficient speakers of L2 English. The authors offer LexTALE as a rough indication of proficiency when no other, more accurate measure is available. Although proficiency certainly entails many skills, LexTALE promises to capture a part of it, i.e. the relationship between vocabulary knowledge and general proficiency (Lemhöfer & Broersma, 2011). As Bialystok and her colleagues (2008) conclude, bilinguals balance their deficits in vocabulary knowledge against their advantages in executive processing when performing lexical retrieval tasks, and confirm that bilingual VF depends both on the verbal proficiency level of the participants and on the executive demands of the task.

The present study investigated VF of L2-immersed on non-immersed Czech-English bilingual adults in the context of executive control in order to understand more precisely the differences in lexical retrieval between the two groups of participants. Therefore, to understand the relative abilities of the two groups in VF tasks and to assess the effect of language background (i.e. immersion) on lexical retrieval, it was necessary to compare the participants on an adequate measure of vocabulary knowledge and in extension verbal proficiency. Providing comparable language proficiency between the L2-immersed and non-immersed bilingual group of participants allows us to distinguish between contribution of vocabulary-related factors to VF performance and factors related to executive control. Using LexTALE, our aim was to support the self-reported proficiency ratings (see chapter 3. 1.) by testing Czech-English bilingual participants in two different linguistic environments (either in Czechia, the linguistic environment of their L1, or in Canada, the linguistic environment of their L2), while other factors such as age, age of acquisition (AoA), age of immersion (AoI), language dominance and level of education were controlled.

3. 2. 1. Method

Stimuli

As described by Lemhöfer & Broersma (2011), LexTALE consists of 60 trials (40 words and 20 nonwords), which were selected from 240 items of an unpublished vocabulary size test developed by Meara et al. (1996). The offered explanation for the higher number of words than nonwords is that some items are so low in frequency that it is unlikely that any of the participants would know them all. The items' length ranges from 4 to 12 letters, and the 40 real words have a mean frequency of between 1 and 26 occurrences per million according to CELEX lexical database. Concerning the words' parts of speech, twelve of the words are adjectives, 15 are nouns, 1 is a verb, 2 are verb participles, 2 are adverbs, and 8 can belong to two different syntactic classes (e.g. both a verb and a noun, such as *dispatch*). In terms of the nonwords, they are orthographically legal and pronounceable nonsense words created by either recombining existing morphemes (such as *rebondicate*) or by changing some letters in an existing word (for instance *proom*). Stimuli were presented in a quiet room with good lighting conditions using a 13-inch laptop screen. The stimuli words and nonwords were displayed one by one in bold letters in the centre of the screen. The order of items was intermixed, such that no more than five words or nonwords appeared in a row.

Procedure

Each participant gave written consent to participate in the present experiment and filled out the adapted version of the Language Experience and Proficiency Questionnaire (LEAP-Q) created by Marian, Blumenfelf and Kaushanskaya (2007) (see Appendix A). Participants were tested individually. The test was administrated online on www.lextale.com. The subjects were seated in a quiet room in front of the laptop screen. The task was explained in Czech by the researcher. The participants were instructed that they would see a series of letter strings and their task is to decide whether it is an existing English word or not. In the former case, they must click on the green *yes* button, in the latter case, they must respond by clicking on the red *no* button (as shown in the Figure 1 below). During completion of the test, a progress report was shown. The instructions were repeated on the screen and they also explained that the task is untimed and the spelling of the items would be British. The test took each participant approximately 4 minutes to complete.

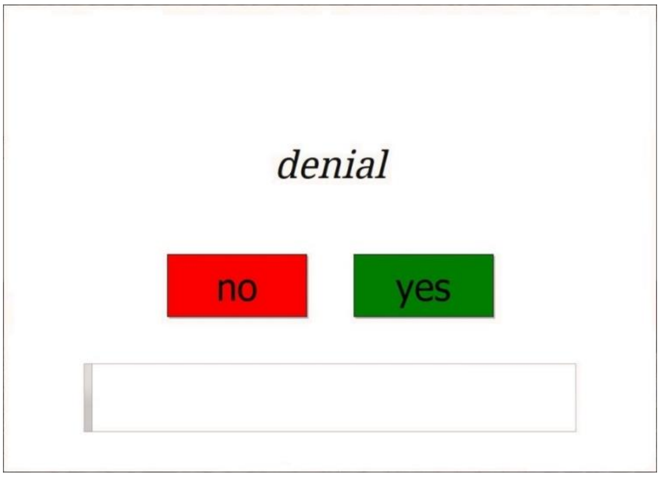

Figure 1. A sample trial of LexTALE

3. 2. 2. Results

The mean and standard deviation values for LexTALE averaged across the two groups of participants are presented in Table 3 below. An independent-samples t-test was conducted to compare LexTALE scores of the immersion group and the non-immersion group. Despite matching self-reported proficiency reported in Table 2, the mean difference in the LexTALE scores of the two groups is nearly-significant, Immersed (M = 76.5, SD = 12.06) and Non-Immersed (M = 85.8, SD = 8.66); t(19) = -1.98, p = .063). According to the relation between general English proficiency levels and LexTALE scores in Marian, Blumenfelf and Kaushanskaya (2007), the non-immersed bilinguals' result falling within the range of 80% - 100% corresponds with C1 & C2 CEF level of proficiency. Whereas the mean result of the immersed group of participants falls within the range of 60% - 80%, which corresponds with B2 CEF level of proficiency (see Figure 2). As explained above, vocabulary knowledge plays a significant factor in VF tasks (Shao et al., 2014), therefore, we had to include this factor when interpreting the data presented in this thesis.

Table 3. LexTALE results (%)

Immersed		**Non-immersed**	
M	*SD*	*M*	*SD*
76.46	12.05	85.83	8.67

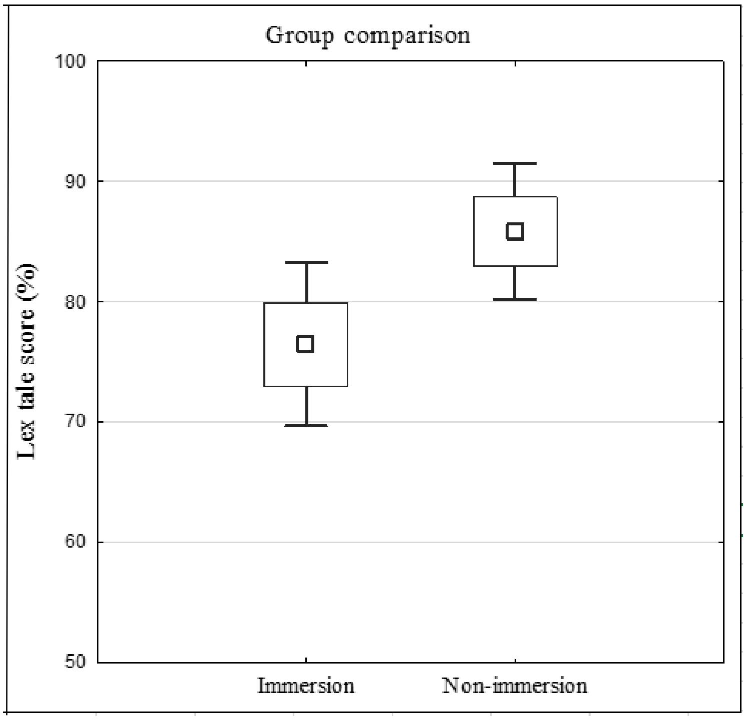

Figure 2. Group comparison of LexTALE scores (%). Whiskers show standard error.

3. 3. Experiment 1: Auditory Backward Digit Span Test

This experiment consisted of Auditory Backward Digit Span Test (BDS), an executive control measure tapping into working memory (= constant updating and manipulation of relevant incoming information while replacing old irrelevant information in a cognitive space). The task was an adaptation of the spatial span subtest in the Wechler Memory Scale-III (WMS-III, Wechsler, 1997). In this experiment, participants are verbally presented randomized sequences of digits (1–9) with performance-adapted list-length adjustment. The participants are required to repeat the numbers in reverse order. Traditional administration of BDS testing begins with lists of 2 digits, and the sequence is increased by one item after every second successful trial, producing two trials for each list-length. Testing continues until the subject fails to correctly reproduce both trials at a given list-length. The task involves reordering of sensory input and complex cognitive processes, which are thought to reflect working memory. This test was included to assess capacity of one of the primary processes of executive system (Miyake et al., 2000) in the two groups of participants and its relationship to the VF scores.

Research has shown that both L1 and L2 processing rely on working memory, a cognitive system considered to facilitate recall, store and process information temporarily when complex cognitive activities are performed. In relation to working memory, there is also a branch of research suggesting that the bilingual advantage is an effect that does not actually exist. For example, Namazi et al. (2010) concluded that controlled attention is a result of enhanced working memory capacity and not a bilingual advantage.

Regarding the role of immersion, the L2 environment may interact with working memory capacity in predicting L2 performance. In Sunderman et al. (2004), L2 learners with some immersion experience showed much smaller effects of span than individuals who were exposed to their L2 only in a classroom. In other words, lower span participants who had immersion experience performed just as well as their higher span immersion peers, whereas lower span participants without immersion experience were generally slower and less accurate at comprehension than their higher span counterparts. These results suggest that immersion experience may provide speakers with external resources that allow them to compensate for having relatively low working memory capacity.

Since the aim of the present thesis is to provide a greater insight into the relationship amongst L2-immersion and presumed EC processes underpinning VF performance, following the methodology by Patra et al. (2019), we used the Auditory Backward Digit Span Test to measure this important executive component, working memory, that could mediate the potential VF differences between the groups of participants. It was conducted only in Czech based on Gutiérrez-Clellen at al.'s (2014) finding that verbal working memory performance can be affected by speaker's proficiency. The study further supported the hypothesis that working memory capacity in not language specific. Working memory is generally considered to be a part of, or closely related to, executive processes, so bilingual advantages might be expected with such paradigms (Bialystok et al., 2009). The goal of this experiment was to measure working memory capacity by testing highly-proficient Czech-English bilingual participants in two different linguistic environments (either in Czechia, the linguistic environment of their L1, or in Canada, the linguistic environment of their L2), while other factors such as age, age of acquisition (AoA), age of immersion (AoI), language dominance, level of education, and the proficiency in L2 were controlled. Despite having similar language skills and features, the two groups of participants differ in their linguistic environment, which we predict causes differences in cognitive control ability depending on the frequency of L2 use.

3. 3. 1. Method

Stimuli

The computerized BDS test was administrated online on www.millisecond.com using Inquisit Lab, a free-to-use software for psychological testing and data collection in diverse research fields. A visual BDS test from the Millisecond library of experiments was adapted for use in this study. Stimuli numbers were presented verbally to the subjects in a quiet room with good acoustic conditions. This experiment followed a digit span procedure as described in Woods et al. (2011): For the duration of 14 trials, a participant is verbally presented with a series of auditory digits from 2 to 9, where each digit is presented for 1 second. Afterwards the participant is asked to correctly recall the digits and repeat them in reverse presentation order. If the response is correct, the participant moves up to the next level (e.g. level 5). If the response is incorrect, the same level is presented for a second time (e.g. level 4). If a consecutive error occurs the participant moves back down to a lower level (e.g. level 3). The order of digits was randomized so that successive digits could not occur in regular ascending or descending sequence (e.g. 1-2 or 2-1), or in ascending or descending odd or even pairs (e.g. 1-3 or 2-4).

Procedure

Each participant gave written consent to participate in the present experiment and filled out the adapted version of the Language Experience and Proficiency Questionnaire (LEAP-Q) created by Marian, Blumenfelf and Kaushanskaya (2007) (see Appendix A). Participants were tested individually. The task was explained in Czech by the researcher. The participants were instructed that they would hear a sequence of randomized numbers in Czech (1–9) at a rate of approximately 1 digit per second, and their task was to correctly recall it in reversed order. A 13-inch laptop was placed in between the experimenter and the participant in such a manner that the screen was visible only to the experimenter. The digit sequences were displayed on the examiner's monitor and responses were recorded by the examiner selecting digits with the computer mouse (as shown in Figure 3 below). The experimenter read numbers aloud with as little rhythm as possible. The sequence demonstrated by the experimenter was repeated by the subjects in reverse order. Each testing session began with two practice trials and contained 14 real testing trials. Each participant received trials with list lengths adaptively adjusted to reflect his/ her performance. The test began with lists of 2 digits with increasingly longer list-length following a 1:2 staircase, i.e. a single correct response increases the length of the subsequent list by one digit, while two incorrect responses are needed to reduce the sequence by one digit. In terms of scoring, in a tradition BDS assessment, the first time a participant makes a consecutive error, the measure Two Error Maximal Length (TE_ML) is set (e.g. if a participant reaches level 8, but answers incorrectly both times, the TE_ML is set to 7). Woods et al. (2011) introduced a new measure Maximal Length (ML), the maximum number of digits a participant recalled correctly during all 14 trials. Hence it is possible for participants to surpass levels they previously failed (e.g. a participant with TE_ML 6 may successfully recall 7 digits on a later try). The task took each participant approximately 5 minutes to complete.

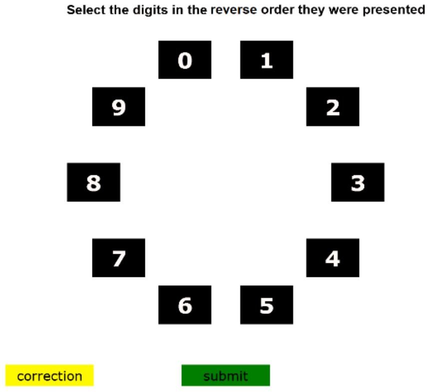

Figure 3. A sample trial of Auditory Backward Digit Span Test

3. 3. 2. Results

With regards to scoring, the two-error maximal length (TE_ML) measure recorded the maximal list length successfully recalled prior to missing two successive lists of the same length. Since digit lists were delivered using a 1:2 staircase, the TE_ML reflected the total number of trials correct prior to two successive misses. The mean and standard deviation values for the BDS test averaged across the two groups of participants are presented in Table 4 below. The BDS data were submitted to the same non-parametric test used in Patra et al. (2019), the Mann-Whitney U test. The test revealed no statistically significant differences between the groups in terms of TE_ML ($U = 45$, $p = 0.55$) and ML ($U = 45$, $p = 0.1$). In many studies measuring working memory span, participants are labelled as “higher” or “lower” working memory span on the basis of a median split of span scores. It is important to mention, that designating the participants as having higher or lower working memory span is relative only to this particular study. In the present thesis, the distribution of higher and lower span participants was even in each group.

Table 4. Summary of mean group performance on Experiment 1.

	Immersed		**Non-immersed**	
	M	*SD*	*M*	*SD*
TE_ML	6.25	1.22	5.89	1.17
ML	6.92	1.0	7	1.0

3. 4. Experiment 2: Verbal Fluency Task

This experiment was focused on the impact of bilingualism and specifically L2-immersion on the performance in a rapid word retrieval task, i.e. oral Verbal Fluency Test also known as Controlled Oral Word Association Test (COWA). Standard administration of the verbal fluency (VF) assessment includes two conditions, namely letter (also called phonetic or phonemic) and category (also called semantic) fluency. The test requires participants to produce as many unique words as possible under time constrains, normally within 60 seconds, that satisfy the stated criteria. In the category fluency condition, participants are asked to produce words which belong to a designated semantic category, for instance animals or fruits (nouns). In the letter fluency condition, participants are asked to generate words which start with a single letter (usually F, A, S) (Borkowski, Benton & Spreen, 1967), excluding proper names of people and places (e.g. *Singapore*), numbers (e.g. *seven*) and variants of the same word (e.g. *borůvka, borůvkový, borůvková*). In both conditions, speakers are given a single cue which activates multiple concepts. Then, they must select one word at a time, while selecting among several alternatives without being given any additional cues to assist the selection of one concept over another, and while also suppressing just produced items, and searching their lexicon to maintain production as fluently as possible. Repeated words and errors are considered incorrect and subtracted from the total score. The total score for each condition is the number of correct responses generated within the one-minute period.

The Verbal Fluency test has been a widely used measure in neuropsychological research to dissociate the roles of efficiency of executive control (letter fluency) and integrity of semantic and lexical representation (category fluency) (Luo et al., 2010). Participants need to retrieve words of the target language, which necessarily requires them to access their mental lexicon, and they need to focus on the task, select words meeting given constraints and avoid repetition, which certainly involves executive control processes. Although both conditions rely on vocabulary knowledge and executive control, each exerts different cognitive demand on word retrieval. The links between words starting with the same letter are likely to be weaker than the same-category words (Shao et al., 2014). As Luo et al. (2010) explain, generating words in the category condition resembles ordinary language use where target lexical items are semantically related, for example a grocery shopping list. According to lexical access models proposing that a word is first selected on the basis of its semantic features, the semantic level is activated before the phonological level (Levelt et al., 1999). Therefore, lexical retrieval based on semantic categories is a largely automatic process of word production and relies primarily on linguistic representation. Whereas performance in letter fluency is more effortful because one has resort to a novel retrieval strategy, and it requires increased frontal executive control to self-monitor and efficiently inhibit inappropriate responses. In addition, the executive demands of the letter fluency task increase when the task is made more difficult by placing restrictions on the words that are acceptable (Bialystok et al., 2008).

There are several studies which have observed performance differences between bilingual and monolingual speakers on verbal fluency tests, for example Sandoval et al. (2010), Gollan et al. (2002) or Rosselli et al. (2000) who demonstrated that bilinguals performed significantly worse on the semantic fluency condition in comparison with their monolingual counterparts. Although the recent research confirms the presence of a bilingual disadvantage in the VF task, the mechanism explaining this disadvantage remains unclear. Costa (2005) and Sandoval et al. (2010) tested possible processes which may account for this disadvantage in VF causing bilinguals to produce fewer correct responses: (1) reduced vocabulary size in bilinguals, (2) slower lexical retrieval due to interference between languages and (3) reduced language-specific language use (weaker links). On the other hand, a number of studies reports bilingual advantage in the letter fluency condition since bilingual individuals often outperform the monolingual speakers (Patra et al., 2019; Gollan et al., 2002; Marsh et al., 2019). Based on the argument that cross-language interference in word retrieval is one of the factors responsible for the enhancement of cognitive control in bilinguals (Bialystok, 2007; Luo et al. 2010), and because executive control plays a decisive role in the letter fluency, bilinguals tend to exhibit better performance. An alternative explanation for this effect was proposed by Gollan & Ferreira (2009) in terms of cognate production. Since cognates are produced by bilinguals more easily (Costa et al., 2000) and letter categories are inherently larger than semantic categories (contains more cognates), cross-language facilitation is stronger in the letter fluency task, thereby reducing the fluency difference between the groups. Nonetheless, Paap et al. (2015) as well as Branzi et al. (2016) or Vega-Mendoza et al. (2015) were unable to replicate these results. Shao and colleagues (2014) did not find a stronger relationship between executive control measures and the performance in letter fluency in comparison with semantic fluency but admitted that selective attention and updating ability may be important in VF performance.

To accomplish the VF task, subjects have to continuously activate new words within a given category or starting with an assigned letter, while monitoring the output to ensure its consistency with the task instructions and suppress irrelevant responses as well as repetitions of prior items, which are retained in working memory (Marsh et al., 2019). Results reported by Shao et al. (2014) reveal that fluency scores depend on the ability to store and update relevant information in working memory, which contributes to good performance in both fluency conditions. Showing a direct relationship between working memory measures and bilingual tasks, Rosen and Engle (1997) demonstrated that individuals with higher working memory span produced more correct items in semantic fluency and fewer perseverations compared to individuals with lower working memory span. Conversely, Luo et al. (2010) they did not find any correlations between working memory and VF results.

Although the exact cognitive processes underlying letter fluency performance are yet to be specified, neuropsychological and neuroimaging studies using fMRI have shown empirical evidence that the VF task is mediated by frontal areas, but letter fluency task also recruits the posterior opercular area of Broca's area involved in cognitive tasks free of language production (Paulesu et al., 1997). The study by Grogan et al. (2009) demonstrated that highly proficient bilingual speakers showed dissociating functional correlates in letter and category fluency tasks as well, resulting in greater activation of different areas. Clinical studies have also established that impaired performance in letter fluency in most apparent in patients with executive dysfunctions (Luo et al., 2010).

The goal of this experiment was to investigate whether L2-immersion influenced the Czech-English bilinguals' (all Czech-dominant) performance on verbal fluency, especially on letter fluency where executive control demands are higher. Using the VF test, we tried to establish whether the role of immersion in the second language environment has an impact on VF tasks by testing highly-proficient Czech-English bilingual participants in two different linguistic environments (either in Czechia, the linguistic environment of their L1, or in Canada, the linguistic environment of their L2), while other factors such as age, age of acquisition (AoA), age of immersion (AoI), language dominance, level of education, and the self-rated proficiency in L2 were controlled. The present study included a standardized English test of vocabulary knowledge and an indicator of general English proficiency, LexTALE. Controlling vocabulary in the samples of participants allowed us to distinguish between contribution of vocabulary-related factors to VF performance and factors related to executive control. While having similar language skills and features, the participants differ in their linguistic environment, which we assumed may cause differences in cognitive control ability and varying results in VF depending on the L1 and L2 use frequency.

As in the previous experiment (the Stroop task), our predictions were based on the bilingual cognitive advantage hypothesis, which stems from the theory of nonselective access to an integrated bilingual lexicon (Green, 1998), simultaneous activation of the target and the non-target language (Kroll et al., 2008), and the hypothesis that the constant exertion of control over the non-target language to avoid cross-language interference leads to an overall enhancement of executive control processes (Bialystok, 2001). Similarly to Heidlmayr et al. (2013), we assumed that the regular use of the L2 (English) in the L2-linguistic environment (Canada) should increase the activation of the L2, and therefore the L2 requires more inhibition in the L2 environment than that of the L1 environment (Czechia), where this language is not commonly used. Bilinguals in the L1-linguistic environment most of the time inhibit only their weaker L2, whereas L2-immersed bilinguals often have to inhibit two languages, namely the regularly activated L2 and the dominant/ automatic L1 (Czech). Hence the more frequent the L2 use, the stronger the inhibitory control.

Regarding the assumptions mentioned above, our initial hypothesis is based on the interaction between linguistic environment (e.g. frequency of L2 use) and Language (L1 vs. L2) for the VF performance. In accordance with the IC and BIA+ models of bilingual language processing, we predict that immersed bilinguals should perform better on L2 verbal fluency (due to higher L2 activation and more enhanced executive control abilities) and worse on L1 verbal fluency (mainly on semantic fluency due to the less activated although dominant and automatic L1) in comparison to the non-immersed participants. Bringing the two strands of testing together, we expect the results from the Stroop test to align with those from the Verbal Fluency tasks for individual participants and the two groups. In other words, we expect the indicator of executive control to predict the number of correct responses, and executive control ability to be relatively more important for letter fluency than for category fluency performance.

3. 4. 1. Method

Stimuli

Two separate experiments were created: a monolingual L1 VF test in Czech and a monolingual L2 VF test in English. In each version, participants completed two verbal fluency conditions, that is, category and letter. The semantic condition required participants to produce words belonging to two different categories similar in size and frequency of exemplars. Concerning the letter condition, participants generated words starting with two different letters. To measure VF in English we followed the procedure employed by Patra et al. (2019), therefore the semantic categories used were *clothing items* and *fruits*, and the letters were *F* and *S*. To measure VF in Czech, according to the method and instructions provided by Nikolai et al. (2015), we selected *animals* and *vegetables* for semantic fluency, and letters *K* and *P* as Czech equivalents of English *F* and *S* in terms of frequency of words in the two languages. Stimuli were presented in a quiet room with good lighting conditions using a 13-inch laptop screen through PowerPoint presentation. The stimuli words and letters were presented both vocally by the researcher and visually in bold letters in size 44 Times New Roman font in the centre of the screen.

Procedure

Each participant gave written consent to participate in the present experiment and filled out the adapted version of the Language Experience and Proficiency Questionnaire (LEAP-Q) created by Marian, Blumenfelf and Kaushanskaya (2007) (see Appendix A). Participants were tested individually. They were seated in front of the laptop screen. The task was explained in Czech by the researcher. Participants were told they would see a letter or a name of a semantic category on the screen as well as a timer showing the remaining time (as shown in Figure 4). They were instructed to produce as many words as possible in 60 seconds, except proper names, numbers, and variants of the same word. These instructions were also repeated prior to the experiments on the screen. At the beginning of each trial, the researcher read aloud the name of the relevant category or the letter and started recording immediately. The experimenter recorded responses by a Samsung tablet using the Audio Recorder application for later analyses. Errors and repetitions were not included in the total word count. Each participant performed the Czech and English version of the VF task on two different days at least one week apart. The two VF tasks were counterbalanced for order of presentation, that is, one half of each group of participants started with Czech version, the other half with English version. Each task took approximately 8 minutes to complete. In total eight recordings were made per each participant, four in Czech and four in English.

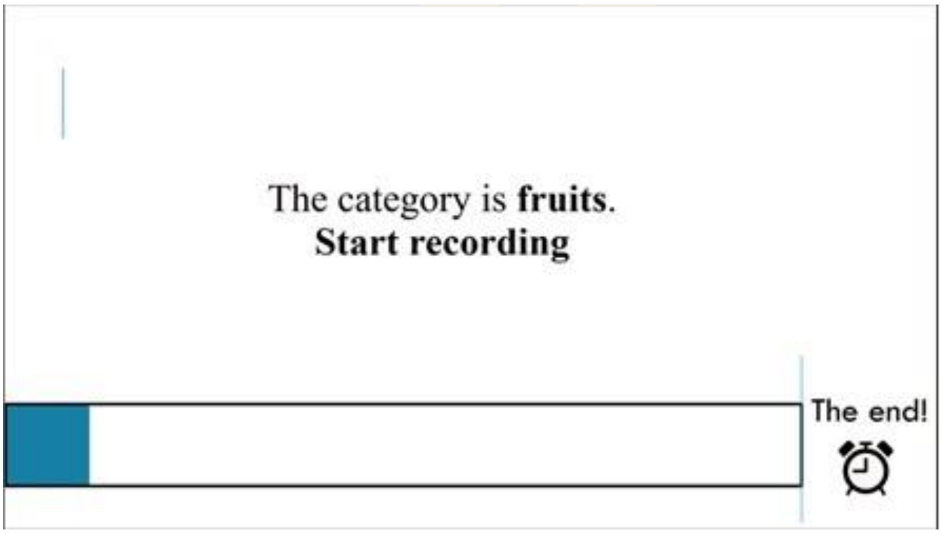

Figure 4. A sample trial in the English version of the category condition of the Verbal Fluency task

3. 4. 2. Results

All responses including repetitions and errors were transcribed verbatim. For a response to be counted correct, it must conform to the given category. In the case of letter fluency, participants had to avoid producing "phonemic parallels", that is, letters that begin with the same onset phoneme as legitimate responses (e.g. *physical*, *phone*) but are illegitimate responses in the context of the specific cue (e.g. produce words that begin with *F*). Errors and repetitions were not included in the total word count. To arrive at the mean scores for each measure, the trials were averaged in each condition. The mean and standard deviation values for the VF variables for Group (i.e. immersed and non-immersed) and Condition (i.e. category and letter) averaged across participants are presented in Table 5 below.

Verbal fluency describes the speed with which an individual can access their stored lexical information, retrieve, and produce exemplars in a short period of time based on content and letter association. Greater speed and production (i.e. a bigger mean number) are interpreted as one of the indicators of the ease with which the mind retrieves words while maintaining a set of constraints. As shown in Figure 5 below, the analysed data supported the view that producing words in L2 takes longer than in L1. Both groups of participants produced on average more words in L1 in both conditions than in L2. Our prediction, that immersed bilinguals should perform worse on L1 verbal fluency than their non-immersed counterparts, was not supported. Our prediction, that immersed bilinguals should perform better in L2 than their non-immersed counterparts, was not supported.

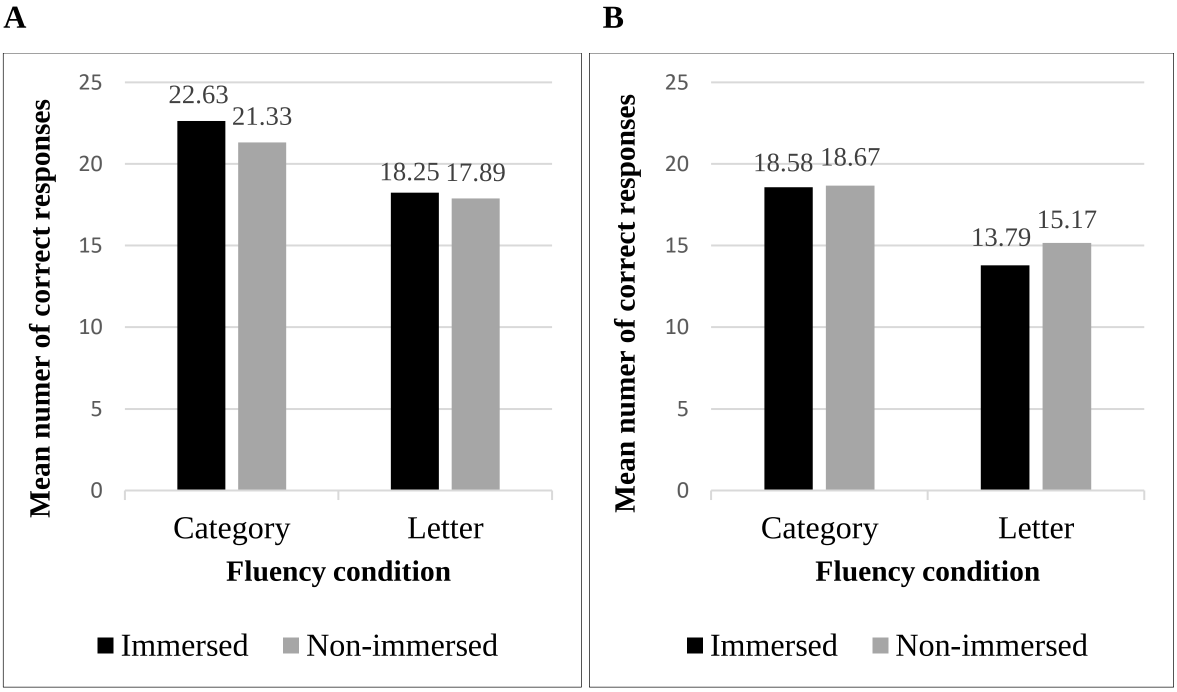

Figure 5. Results of (A) the Czech and (B) the English Verbal Fluency task.

Table 5. Summary of mean group performance on Experiment 2

	Immersed		**Non-immersed**	
Czech VF	*M*	*SD*	*M*	*SD*
P	18	4.26	18.56	3.50
K	18.5	3.63	17.22	3.42
Letter Total	18.25	0.35	17.89	0.94
Animals	29.33	6.27	28.44	6.06
Vegetable	15.92	3.99	14.22	4.15
Category Total	22.63	9.48	21.33	10.05
FDS	0.16	0.24	0.12	0.26
English VF				
F	12.33	3.75	13.56	4.67
S	15.25	2.22	16.78	3.35
Letter Total	13.79	2.06	15.17	2.28
Clothing items	21.5	2.65	23.11	6.77
Fruit	15.67	3.11	14.22	2.99
Category Total	18.58	4.12	18.67	6.28
FDS	0.24	0.18	0.17	0.21

Notes: For each VF task, the number of correct responses per minute is reported.

We subjected the collected data to an analysis of variance (RM ANOVA) in which the *sum* of the scores on two letter categories and the two semantic categories was considered as a dependent variable, Group (Immersed, Non-Immersed) was considered as a between-subject variable, and Language (Czech, English) and Test (Phonological, Semantic) as within-subject variables. The analysis showed a significant effect of Language ($F = 35.50$, $MS = 992$, $p < .001$) and Test ($F = 24.20$, $MS = 1335$, $p < .001$), nonetheless, there was no significant Group effect. We ran another RM ANOVA analysis with the same between-subject variable (Group) and within-subject variables (Language, Test), but this time with the *average* of the scores on two letter categories and the two semantic categories as a dependent variable. Again, there was a significant main effect of Language on bilinguals' verbal fluency scores ($F(1, 19) = 35.50$, $p < .001$) and a significant main effect of Test on bilinguals' verbal fluency scores ($F(1, 19) = 24.20$, $p < .001$).

Moving beyond the number of correct responses, Patra et al. (2019) employed a wide range of variables to characterize VF performance, such as Fluency Difference Score

(FDS), which measures the ability to maintain the performance in the demanding condition (i.e. letter fluency). The FDS has been suggested to further capture the role of executive control in VF task. It is calculated by the difference in the number of correct responses between the letter and semantic fluency conditions as a proportion of correct responses in the semantic fluency condition (Friesen et al., 2015). Individuals with better performance in the letter fluency performance would show a smaller FDS, which is indicative of better executive control abilities (Patra et al., 2019). Again, there were not significant differences ($p > 0.05$) between the two groups of participants.

3. 5. Experiment 3: Stroop Task

This experiment was focused on the impact of one executive function, inhibitory control in bilingualism, on the performance of an executive task, i.e. the Stroop task (Stroop, 1935). The Stroop task has become a paradigmatic measure of selective attention (the ability to suppress highly potent competitors to a target response) since its introduction 85 years ago. This task has also been used to demonstrate the advantages of bilingualism on cognitive control, a set of processes which include, but are not limited to, inhibition, attention, conflict resolution, selection and monitoring (Sabourin & Vinerte, 2014). In this task, participants must respond only to the relevant cues whilst conflicting mental representations are active, each associated with different response (Bialystok et al., 2006). Participants are shown words written in different coloured inks and asked to respond to the colour of the ink. In other words, the ink colour must be identified while ignoring the meaning of the word itself. In the congruent condition, the written word and ink colour match (i.e. the word *red* written in red ink). However, the task is more challenging in the incongruent condition, when the written word does not correspond to the ink colour (i.e. the word *red* written in green ink). The difference in response times (RT) in incongruent and congruent trials is termed the “Stroop effect”, which has been attributed to the competition created by the process of responding to the ink colour interfering with the automatic process of reading. As Heidlmayr et al. (2013) explain, because word reading is more automatic than colour identification, executive control (predominantly inhibition) is required to suppress the tendency to respond on the basis of the word rather than the ink colour. Stroop task is a complex inhibition task involving a higher working memory demand that requires subjects to hold a verbal rule in mind, respond according to it, and inhibit an automatic response and the non-target language (which is more demanding for high-proficiency languages).

Although there is no clear-cut relation between bilingualism and conflict resolution in executive tasks, there is a number of studies which observed that bilinguals find it easier to solve conflicts occurring in tasks like the Stroop task, for example Bialystok et al. (2008) or Badzakova-Trajkov (2008), who used the Stroop task to demonstrate that bilinguals were better in interference suppression compared to their monolingual counterparts. One plausible explanation which may account for this advantage is that bilinguals' inhibition is enhanced due to frequent code switching in their daily lives in comparison to monolinguals. On the contrary, some studies using the Stroop task find no bilingual advantages in inhibitory control in a sample of bilingual adults, such as Kousaie and Phillips (2012). Long & Prat (2002) demonstrated that individuals with higher working memory span were better able to prevent Stroop interference than individuals with lower working memory span, but only when the number of conflict trials was high. Paap et al. (2015) propose that if a bilingual Stroop advantage exists, it is rather elusive and it can be observed only under particular circumstances.

Both Heidlmayr et al. (2013) and Coderre et al. (2013) identify L2-immersion as a possible factor in Stroop task performance. Following the approach of Heidlmayr et al. (2013) to the impact of frequency of use of an L2 in the daily life of successive bilinguals on the efficiency of their inhibitory control mechanism, the goal of this experiment was to investigate whether the L2-immersion influenced the Czech-English bilinguals' performance on conflict resolution. Using the Stroop task, we examined the role of immersion in the second language environment in inhibitory control by testing highly-proficient Czech-English bilingual participants in two different linguistic environments (either in Czechia, the linguistic environment of their L1, or in Canada, the linguistic environment of their L2), while other confounding variables such as age, age of acquisition (AoA), age of immersion (AoI), language dominance, level of education, and the self-rated proficiency in L2 were controlled. As noted by Marsh et al. (2019), one of the factors that influences the ease of cross-language suppression is the similarity between languages, that is, less similar languages show weaker between-language interference.

In the present thesis, predictions were based on a bilingual cognitive advantage hypothesis, which stems from the theory of nonselective access to an integrated bilingual lexicon (Green, 1998) and simultaneous activation of the target and the non-target language (Kroll et al., 2008). The constant exertion of control over the non-relevant language to avoid cross-language errors leads to an overall enhancement of executive control processes resulting in better performance on the Stroop task and other linguistic and non-linguistic tasks (Bialystok, 2001). Despite having similar language skills and features, the two groups of participants differ in their linguistic environment, which we predicted may cause differences in cognitive control ability and varying size of the Stroop effect depending on the L2 use frequency. Similarly to Heidlmayr et al. (2013), we assumed that the regular use of the L2 (English) in the L2-linguistic environment (Canada) should increase the activation of the L2, and therefore the L2 requires more inhibition in the L2 environment than that of the L1 environment (Czechia), where this language is not commonly used. Bilinguals in the L1-linguistic environment most of the time inhibit only their weaker L2, whereas L2-immersed bilinguals often have to inhibit two languages, namely the regularly activated L2 and the dominant/ automatic L1 (Czech). This was supported by Linck et al. (2009) in their study of L2 immersed learners and classroom learners; the overall pattern of results suggests that in the L2 immersion context, the L1 is actively inhibited. Consequently, the more frequent the L2 use, the stronger the inhibitory control due to the regular use of L2 (Heidlmayr et al., 2013).

Based on these assumptions, our initial hypothesis is built upon the interaction between Linguistic environment (i.e. frequency of L2 use) and Language (L1 vs. L2) for the Stroop effect. In accordance with the IC and BIA+ models of bilingual language processing, the Stroop effect is predicted to be larger in the L1 than in the L2 due to the higher activation and automaticity of the L1. However, this difference might decrease as the frequency of L2 use increases and becomes more automatic causing a larger Stroop effect in L2. Moreover, the Stroop effect of L2-immersed bilinguals could decrease in L1 due to its reduced activation. Inhibition may therefore be more efficient in the lower activated L1 in the immersed bilinguals in comparison to non-immersed participants. We also predicted that when the interfering (incongruent) stimuli are in L1, there is an advantage for bilinguals in the immersion situation. When the interfering (incongruent) stimuli are in L2 the non-immersed bilinguals should perform better.

3. 5. 1. Method

Stimuli

The manual Stroop tasks were programmed using PsyToolkit, a free-to-use software for running cognitive-psychological experiments and surveys developed by Professor in Psychology Gijsbert Stoet. A computerized Stroop task from the freely available PsyToolkit library of experiments was adapted for use in this study. Two separate experiments were created. First, a monolingual L1 Stroop task in Czech, which consisted of Czech congruent and Czech incongruent items intermixed. Second, a monolingual L2 Stroop task in English, which consisted of English congruent and English incongruent items intermixed. These experiments did not include any control items. Stimuli were presented in a quiet room with good lighting conditions using a 13-inch laptop screen. Colour stimuli consisted of red, blue, green and yellow letters inside black rectangles of 315 x 81 pixels presented individually on a black background. The stimuli words used were *red*, *blue*, *green* and *yellow* for English, and *červená, modrá, zelená* and *žlutá* for Czech. The four universal focal colours, which are deeply entrenched in the lexicon, were chosen with respect to the consensus in the literature. Words were presented in bold capital letters in size 36 Arial font in the centre of the screen, and could appear in either the congruent condition (i.e. the word *red* written in red font), or incongruent condition (i.e. the word *red* written in yellow font) as shown in Figure 6 below. The word and colour stimulus appeared simultaneously.

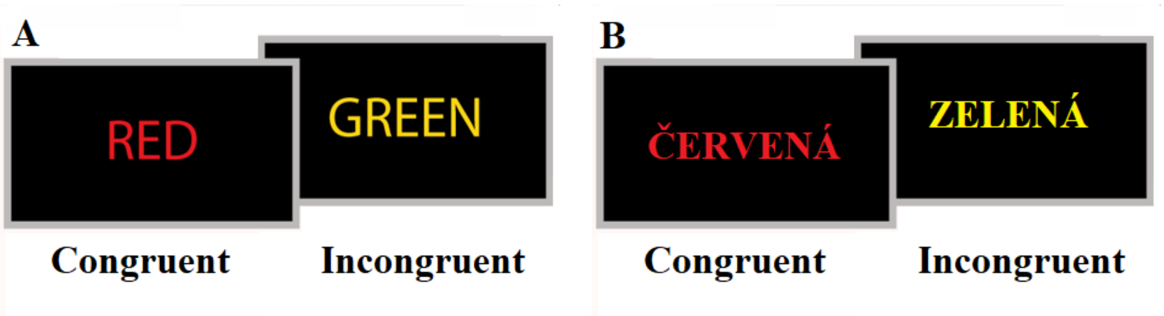

Figure 6. Incongruent and congruent conditions in (A) the English Stroop task and in (B) the Czech Stroop task.

Procedure

Each participant gave written consent to participate in the present research and filled out the adapted version of the Language Experience and Proficiency Questionnaire (LEAP-Q) created by Marian, Blumenfelf and Kaushanskaya (2007) (see Appendix A). Participants were tested individually. They were seated in front of the laptop in a common writing position with their right hand positioned on the keyboard. The task was explained in Czech by the researcher. Participants were told they would see words in different colours appear on the screen. They were asked to indicate as fast and as correctly as possible the colour of the font the word was presented in by pressing one of the four assigned keys that corresponded with the colours (e.g. if the word *red* appears in yellow font, participant have to press the yellow key). A manual Stroop task, in which participants indicate the colour using buttons/ keys, was employed in this study to eliminate the influence of overt word production processes and to obtain instant RT results. Due to the inconsistency in choice of buttons and fingers in studies using a Stroop task, we opted for our own response strategy. Participants were asked to use only their right-hand index finger to press the corresponding keys marked with colour patches on the keyboard. The keys *f, v, b* and *h* were chosen in both Stroop tasks to facilitate the colour-key-assignment due to their similar proximity to the key *g*, as shown in Figure 7. After each trial, participants were asked to return with their index finger back to the letter *g* to ensure fair conditions for each response key.

Figure 7. Layout of the four response keys and colours on the keyboard.

Participants were instructed to keep their gaze fixated in the centre of the screen. These instructions were also repeated prior to the experiments on the screen. Each task contained a total of 60 real testing trials preceded by 10 practise trials to help the participants with the initial finger-to-colour mapping. In order to give them the opportunity to ask questions, the researcher remained in the room during the practise trials. Once the practise trials were completed and there were no further questions, the researcher left the room and the real data collection began. At the beginning of each trial a fixation cross appeared in the centre of the screen for 200 ms followed by a blank screen for 100 ms, then the onset of the target followed. When the target appeared on screen, it remained there until the participant by pressing a key or 500 ms had elapsed (see Figure 8). Then, feedback (correct/ wrong) appeared and the next trial began. RTs of congruent and incongruent trials were recorded and analysed. Each participant performed the Czech and English version of the Stroop task on two different days at least one week apart. The two Stroop tasks were counterbalanced for order of presentation, that is, one half of each group of participants started with Czech version, the other half with English version. Each task took approximately 5 minutes to complete for each participant.

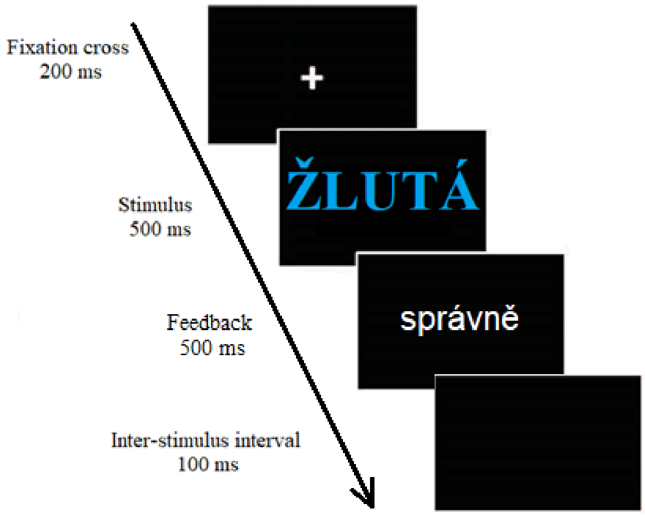

Figure 8. The timing of a sample trial in the Czech version of the Stroop task.

3. 5. 2. Results

As explained above, the Stroop task is a paradigm in which a dominant response tendency must be inhibited. The Stroop effect is calculated by subtracting the mean response times in the congruent condition from the mean response times in congruent condition. Response time data is displayed in Figure 9 and Table 6 below. Shorter RTs in the incongruent condition, hence a smaller Stroop effect, are interpreted to reflect stronger inhibitory control mechanism (Heidlmayr et al., 2013). In line with the literature, the mean latencies are longer in the incongruent condition, where participants are expected to resist the misleading information. Our prediction, that there should an advantage for the L2-immersed bilinguals in the incongruent condition in the Czech Stroop task, was not supported. Our prediction, that there should be an advantage for the non-immersed bilinguals in the incongruent condition in the English Stroop task, was not supported.

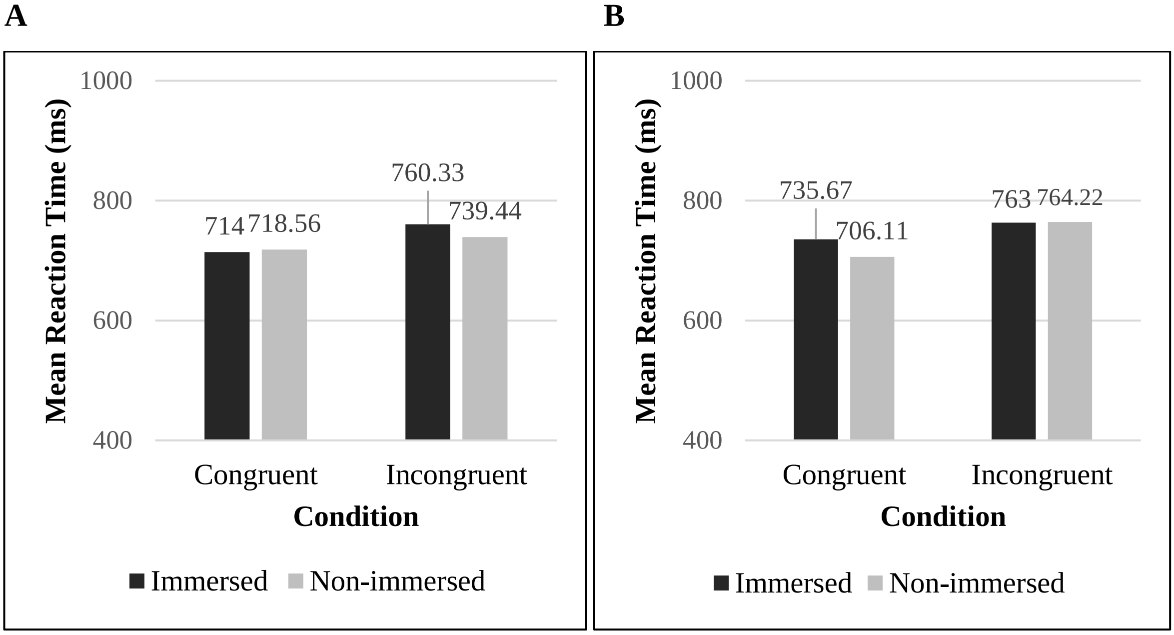

Figure 9. Mean RTs in incongruent and congruent conditions in (A) the Czech Stroop task and in (B) the English Stroop task.

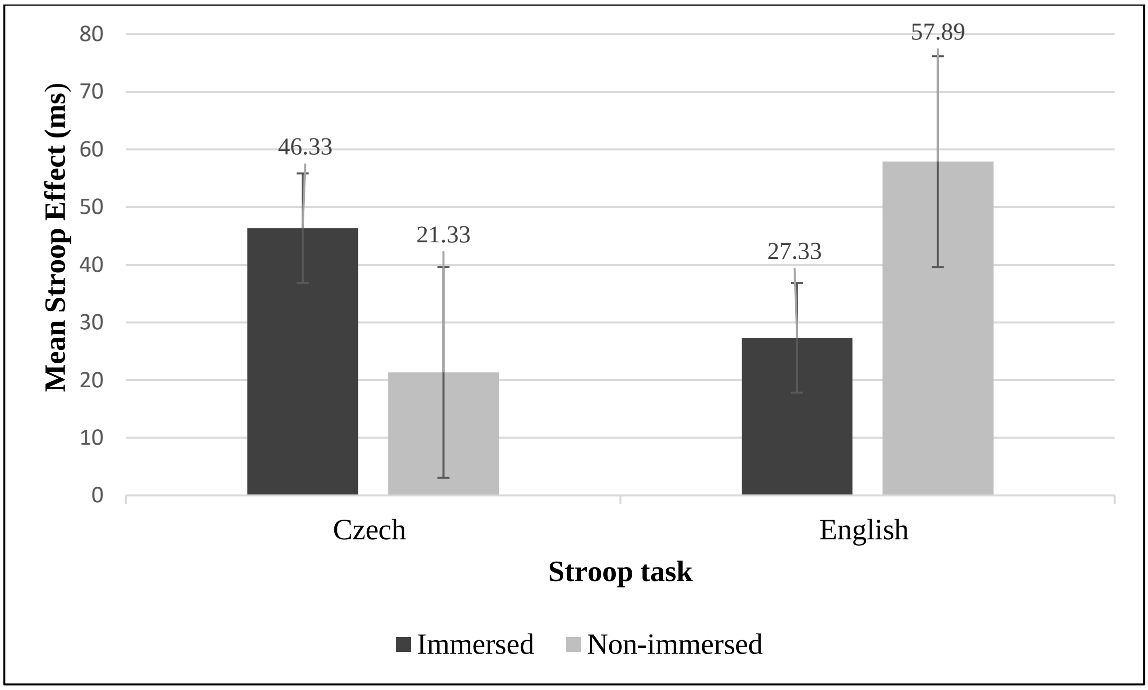

Figure 10. Mean Stroop effects in the Czech and English Stroop tasks. Error bars represent Standard Error.

We subjected the results of response times to an analysis of variance (RM ANOVA) in which RT was considered as a dependent variable, Language (L1 Czech, L2 English) and Condition (Congruent, Incongruent) were considered as a within-group variable, and Group (Immersed, Non-Immersed) as a between-subject variable. The analysis showed a significant effect of Stroop Condition (Congruent vs. Incongruent) (F =

31.38, MS = 3.00E + 04, p < .001) and a nearly significant three-way Language X Condition X Group interaction (F = 3.45, MS = 4064, p = 0.079), which we examined further in a post-hoc Tukey test to see if any of the partial comparisons are significant. The results of the test indicated that the Stroop effect showed up when non-immersed bilinguals used L2 (p = 0.033). Moreover, the results, which just missed significance of 0.05 (p = 0.059), indicated that the Stroop effect also showed up for immersed bilinguals when they used Czech. To cross-check the results, we ran another RM ANOVA on the Stroop task, in which Group (Immersed, Non-Immersed) was considered as between-subject variable and Language (Czech, English) as a within-subject variable. Neither Language nor Group interaction turned out significant (F1(19) = 3.3409, p = 0.083).

Table 6. Summary of mean group performance on Experiment 3.

	Immersed		**Non-immersed**	
CZ Stroop task	*M*	*SD*	*M*	*SD*
Congruent	714	70.11	718.56	90.49
Incongruent	760.33	63.5	739.44	80.99
Stroop effect	46.33	56.93	21.33	43.58
EN Stroop task				
Congruent	735.67	73.52	706.11	93.17
Incongruent	763	71.35	764.22	78.96
Stroop effect	27.33	36.75	57.89	43.82

Notes: Mean RTs are reported in ms.

Table 7. Means (M), standard deviations (SD), and statistical results of all the measures.

Measures	Immersed *M*	Immersed *SD*	Non-immersed *M*	Non-immersed *SD*	Statistical Results			
LexTALE	76.5	12.06	85.8	8.66	t(19) = -1.98, ***p* = .063**			
Backward Digit Span								
Two-error Max Length	6.25	1.22	5.89	1.17	t(19) = 0.06, p = .5			
Maximal Length	6.92	1.00	7.0	1.0	t(19) = -0.19, p = .85			
Verbal Fluency correct responses								
Semantic (Czech)	22.63	9.48	21.33	10.05	Group	Fluency task	Language	No significant interactions.
Letter (Czech)	18.25	0.35	17.89	0.94	F(1, 19) = .002	F(1,19) = 24.2	F(1,19)= 35.5	
Semantic (English)	18.58	4.12	18.67	6.28	p = .96	***p* = < .001**	***p* = < .001**	
Letter (English)	13.79	2.06	15.17	2.28				
Fluency Difference Score					Group	Language		Interaction not significant.
FDS in Czech	0.164	0.236	0.124	0.261	F(1, 19) = .5	F(1, 19) = 1.37		
FDS in English	0.246	0.185	0.17	0.214	p = .49	p = .25		
Stroop task								
Stroop incongruent RT (Czech)	760.33	63.5	739.44	80.99	Group	Trial	Language	Near-significant Group*Trial* Language F (1,19) = 3.45, p = .079
Stroop congruent RT (Czech)	714	70.11	718.56	90.49	F(1, 19) = .212	F(1,19) =31.38	F(1, 19)=.181	
Stroop incongruent RT (English)	763	71.35	764.22	78.96	p = .65	***p* < .001**	p = .67	
Stroop congruent RT (English)	735.67	73.52	706.11	93.17				

3. 6. Discussion

The present thesis aimed at examining the impact of L2-immersion experience on executive functions and verbal fluency by testing healthy immersed and non-immersed Czech-English sequential bilingual speakers by means of LexTALE, the Stroop task in Czech and English, the Verbal Fluency task in Czech and English and the Auditory Backward Digit Span test in Czech. Following the methodology by Patra et al. (2019), we measured language proficiency, verbal fluency, inhibitory control in conflict resolution, and working memory to analyse the linguistic and executive control mechanisms of the participants' performance.

Based on the BIA+ model (Dijkstra & Van Heuven, 2002), we assumed that the regular use of the L2 in the L2-linguistic environment should increase the activation of the L2 for the immersed group of participants compared to the non-immersed group. We also assumed that the level of activation of the L1 should decrease in the L2-environment, where the language is not commonly used. According to the IC Model, the stronger/ more activated the language is, the more interference/ competition takes place, and the more inhibition needs to be applied (Green, 1998). Therefore, we assumed that the practised suppression ability of bilinguals in the immersion situation should be better, since they often need to inhibit both their dominant L1 and frequently used, hence highly activated, L2 as all immersed participants reported use of Czech to some extent. Bilinguals in the L1-linguistic environment most of the time inhibit only their weaker, less activated L2 and that requires less inhibitory control. In other words, immersed bilinguals face bigger cross-language interference than their non-immersed counterparts, that is, L1 of the immersed participants is affected more by L2 than L1 of the non-immersed participants, which could lead to enhanced inhibitory control according to the bilingual cognitive advantage hypothesis (Bialystok, 2001).

When recruiting participants, we strived for a homogenous sample of bilinguals with respect to confounding variables which could play a role in assessing bilingual executive functions and VF performance, which we hoped would decrease the within-group variability and findings could be attributed to the examined processes. The first two tests (LexTALE and BDS) describe the participants' capacities. We did not expect any differences between the two groups on these measures. If we could ensure similar language proficiency and also the working memory capacity, then any potential differences in

Verbal Fluency or the Stroop task could be interpreted in terms of inhibitory control. The mean difference between the groups' LexTALE scores missed the significance level $p < 0.05$ ($p = 0.063$), which could indicate richer vocabulary knowledge of one of the two groups. According to the relation between general English proficiency levels and LexTALE scores in Marian, Blumenfelf and Kaushanskaya (2007), the non-immersed bilinguals' result falling within the range of 80% - 100% corresponds with C1 & C2 CEF level of proficiency. Whereas the mean result of the immersed group of participants falls within the range of 60% - 80%, which corresponds with B2 CEF level of proficiency. This measure supported the self-reported proficiency scores and confirmed the homogeneity of the sample with respect to their vocabulary knowledge and general proficiency in English, which was crucial to eliminate within-group variability.

Memory measures, such as the auditory BDS task used in the present thesis, test the ability to maintain activation of multiple representations and the ability to inhibit irrelevant information simultaneously. As mentioned in the chapter 3.3., there is a body of research that proposes a relation between working memory capacity and bilingual performance based on the argument that these types of tasks require an efficient suppression mechanism that limits the amount of interfering information in working memory. Using the same non-parametric test used in Patra et al. (2019), the Mann-Whitney U test, the results yielded by this experiment in Czech revealed no statistically significant differences between the two groups in terms of TE_ML ($U = 45$, $p = 0.55$) and ML ($U = 45$, $p = 0.1$). Again, this finding allowed us to attribute potential differences between the groups in the VF or Stroop task to inhibitory control mechanism, if there were any.

With regards to the Verbal Fluency task, surprisingly, the reported data did not confirm our initial predictions that immersion bilinguals should perform better on L2 verbal fluency and worse on L1 verbal fluency in comparison to non-immersion bilinguals. Subjecting the collected data to RM ANOVA analysis, there were no significant differences between the immersed and non-immersed participants with respect to the sum and average numbers of correct responses. However, in line with the literature, further analysis of the mean correct responses proved that Language (L1 vs L2; $p = < .001$) and Test (Letter vs Category; $p < .001$) are indeed significant factors in bilinguals' verbal fluency performance. Moving beyond the number of correct responses, as in Patra et al. (2019), we employed Fluency Difference Score (FDS), which measures the ability to maintain the performance in the demanding condition (i.e. letter fluency), that is, executive control in VF task. Again, there was no significant Group difference ($p > 0.05$). Even above-average immersed participants in terms of length of immersion (*M* = 3.86, *SD* = 2.84; *n* = 4) in comparison with the non-immersed participants did not show any significant advantage in verbal fluency or inhibitory control ($p > 0.05$).

Concerning the data yielded by the Stroop task, our predictions that when the incongruent stimuli are in L1 there is an advantage for bilinguals in the immersion situation, and when the incongruent stimuli are in L2 the non-immersion bilinguals should better, were not confirmed. Subjecting the mean Stroop effects and RTs to RM ANOVA analysis, the experiment did not reveal any statistically significant between-group differences in inhibitory control ($p > 0.05$). Further analysis showed a significant effect of Stroop Condition (Congruent vs. Incongruent; $p < .001$), which proved effectiveness of the design of the tests, and a nearly significant three-way Language X Condition X Group interaction ($p = 0.079$), which was examined in a post-hoc Tukey test to see if any of the partial comparisons are significant. The results of the test indicated that the Stroop effect showed up when non-immersed bilinguals used English ($p = 0.033$) meaning that they had to apply inhibitory control when using L2. The results, which just missed significance of $p < 0.05$ ($p = 0.059$), indicated that the Stroop effect also showed up for immersed bilinguals when they used their L1, Czech.

Bringing the two strands of testing together, we expected the results from the Stroop test to align with those from the Verbal Fluency tasks for individual participants and the two groups. Data collected in these two experiments correspond with each other as there were no significant group differences that could be attributed to immersion experience in the L2 linguistic environment in bilingual adults.

Apart from discussing results of the individual tests, this chapter includes also a general discussion bringing the results together. Analysis of the correlation coefficients amongst the measures in the Czech tests and the English tests showed two significant and positive correlations between Czech and English letter fluency conditions ($r = 0.47$, $p < 0.05$), and between English and Czech semantic fluency condition ($r = 0.45$, $p < 0.05$), i.e. the number of correct responses in one condition in one language is positively dependent on the performance in the relevant condition in the other language. Concerning correlation coefficients amongst the measures within a language, in the Czech data, there was a significant positive correlation between FDS and the Stroop effect ($r = 0.46$, $p < 0.05$), i.e. the participants who showed better executive control in the VF task also demonstrated better inhibitory control in the Stroop task. In the English data, there was a significant and negative correlation between the Fluency Difference Score in verbal fluency and Maximal Length in the BDS test ($r = -0.51$, $p < 0.05$) in a way that the higher ML, the smaller FDS. In other words, the participants who demonstrated better working memory span had also better executive control (in terms of lower FDS), which helped them to perform better in the difficult fluency condition (i.e. letter fluency) in the English VF task.

4 CONCLUSION

The present thesis was aimed at extending research of bilingualism by examining the impact of the linguistic factor that has not been taken systematically into consideration, i.e. immersion experience in the L2 linguistic environment, on executive functions and the efficiency of word retrieval. Based on the argument that bilingual advantage is modulated by the duration of immersion in a second language environment (Heidlmayr et al., 2013), we hypothesized that the frequency of the L2 use, depending on the linguistic environment, could cause an effect on inhibitory control and verbal fluency. Our predictions stemmed from the bilingual cognitive advantage hypothesis, which is based on the nonselective access to an integrated bilingual lexicon (Green, 1998), simultaneous activation of the target and the non-target language (Kroll et al., 2008), and the hypothesis that the constant exertion of control over the non-target language to avoid cross-language interference leads to an overall enhancement of executive control processes (Bialystok, 2001). However, the reported data did not support the predictions.

For the present thesis we adopted the framework employed by Patra et al. (2019). This framework proposes that it is necessary to use separate measures of verbal fluency and executive control abilities to address and explain bilingual advantages and disadvantages. Specifically, we measured the following: inhibitory control by means of the Stroop task in Czech and English, working memory by means of Auditory Backward Digit Span test in Czech, and verbal fluency by means of the Verbal Fluency task in Czech and English. To examine the role of immersion experience on the efficiency of the executive control mechanism and verbal fluency performance, we tested a homogenous sample of highly-proficient immersed and non-immersed Czech (L1) – English (L2) sequential bilinguals in two different linguistic environments (either in Czechia, or in Canada), while other confounding variables such as age, age of acquisition, age of immersion, language dominance, level of education, proficiency in L2, and working memory capacity were controlled, so the findings could be attributed to the examined processes only. Unfortunately, as a consequence of the unforeseen Covid-19 pandemic, we could not reach the goal number of participants in the non-immersed group.

The first part of this thesis summarized recent findings and hypotheses concerning bilingual advantages and disadvantages providing a background for our points of departure and justification for the approach taken in this thesis. The next chapter described and compared models of bilingual language processing, such as IC Model or BIA+ model, postulating that active inhibition occurs when non-target language is inhibited (Green, 1998). The following part was concerned with description of the employed measures and experiments and reported results of the individual tests to determine whether or not there were any significant differences between the two groups of participants with respect to inhibitory control or verbal fluency. The discussion addressed results yielded by statistical analyses of the individual tests as well as correlations between the tests in Czech and English and between the measures within the two languages to provide a general discussion of the performance of the individual participants.

Addressing the stated research questions, within the scope of this thesis, we did not find any statistically significant verbal or cognitive advantages induced by L2-immersion experience in adulthood that could be reflected in verbal fluency performance or conflict resolution. In other words, analyses of our results did not show superior use of executive processes, namely inhibitory control, or better lexical retrieval among adult L2-immersed bilinguals in comparison with non-immersed bilinguals that can be attributed to the impact of linguistic environment. Therefore, the answers to both questions are negative. Nonetheless, to conclude on a positive note, language immersion experience is a personal enrichment and a passport to other cultures. Bilinguals must be viewed under a magnifying glass before their processing costs can be seen, and the advantages of bilingualism as well as L2 immersion experience whether cognitive, practical, or cultural certainly outweigh the costs.

LIST OF ABBREVIATIONS

AoA – Age of Acquisition

AoI – Age of Immersion

BDS – Backward Digit Span

BIA+ – Bilingual Interactive Activation+

bLC – Bilingual Language Control

EC – Executive Control

EF – Executive Function

FDS – Fluency Difference Score

IC – Inhibitory Control

L1 – First/ Dominant Language

L2 – Second Language

L3 – Third Language

LEAP-Q – Language Experience and Proficiency Questionnaire

M – Median

ML – Maximal Length

n – Sample size

n/a – Not applicable

RHM – Revised Hierarchical Model

RT – Reaction/ Response Time

SD – Standard Deviation

TE_ML – Two Error Maximal Length

VF – Verbal Fluency

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ABSTRACT

Title:	The Impact of Bilingualism on Verbal Fluency and Executive Functions: The Case of L2-Immersed and Non-Immersed Czech-English Bilinguals
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Abstract: Research has shown that bilingualism affects linguistic performance in L2 as well as L1. Moreover, much recent research has been dedicated to determining whether bilingualism leads to benefits across a variety of different cognitive functions such as inhibitory control, mental-set shifting and working memory.

The aim of this thesis is to investigate the consequences of bilingualism for verbal fluency and executive functions by comparing bilinguals in an immersion situation to bilinguals in a non-immersion L1 context. It is based on the assumption, that bilingual lexical retrieval requires the ability to inhibit the non-target language while the person is speaking the target language since both languages are activated [Kroll, Bobb, Misra, & Guo, 2008]. We want to test bilingual’s inhibitory control for our two groups of bilinguals, for example with the use of Stroop test administered in L2 and also in L1. Our initial hypothesis is that when the interfering (incongruent) stimuli are in L1 there is an advantage for bilinguals in the immersion situation. When the interfering (incongruent) stimuli are in L2 the non-immersion bilinguals should better.

Simultaneous language activation could explain the so called "bilingual disadvantage" during lexical retrieval [Sandoval, Gollan, Ferreira, & Salmon, 2010], shown for example by bilinguals’ poorer performance in verbal fluency tasks compared to monolinguals, especially in semantic fluency. We could try to establish whether linguistic environment, i.e. immersion vs. non-immersion situation, has an impact on verbal fluency tasks. Our initial hypothesis would be that immersion bilinguals should perform better on L2 verbal fluency and worse on L1 verbal fluency in comparison to non-immersion bilinguals.

Bringing the two strands of testing together, we expect the results from the Stroop test to align with those from the verbal fluency tasks for individual participants and the two groups.

Key words: bilingualism, cognitive functions, executive functions, verbal fluency, immersion, bilingual disadvantage, bilingual advantage, inhibitory control

ANOTACE

Název práce:	The Impact of Bilingualism on Verbal Fluency and Executive Functions: The Case of L2-Immersed and Non-Immersed Czech-English Bilinguals
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Abstrakt: Výzkum prokázal, že znalost dvou a více jazyků do jisté míry ovlivňuje jazykový výkon v každém z těchto jazyků. Nedávné studie se snažili určit, zda bilingvismus přináší výhody pro řadu kognitivních funkcí jako je inhibice, mentální flexibilita nebo pracovní paměť.

Cílem této práce je prozkoumat důsledky bilingvismu pro verbální fluenci a exekutivní funkce porovnáním bilingvních mluvčích v imerzní situaci (v tomto případě anglofonní) a bilingvních mluvčích v neimerzním jazykovém prostředí (v tomto případě českém). Práce vychází z hypotézy, že lexikální přístup bilingvních mluvčích během používání cílového jazyka vyžaduje schopnost inhibice druhého jazyka, jelikož oba jazyky jsou současně aktivovány [Kroll, Bobb, Misra, & Guo, 2008]. Inhibiční kontrolu obou skupin chceme otestovat pomocí Stroopova testu v mateřském/ českém i druhém/ anglickém jazyce. Naše počáteční hypotéza je taková, že pokud podněty interferují v L1 (jsou nekongruentní), budou ve výhodě bilingvní mluvčí v imerzní situaci. Pokud podněty interferují v L2, budou ve výhodě bilingvní mluvčí v neimerzní situaci.

Simultánní aktivace jazyků by mohla vysvětlit jev tzv. „bilingual disadvantage“ při vybavování lexémů [Sandoval, Gollan, Ferreira, & Salmon, 2010], který se například projevuje v horším výkonu bilingvních mluvčích v testech verbální fluence oproti monolingvním jedincům, a to především v sémantické fluenci. Pokusíme se určit, zda má jazykové prostředí, tedy imerzní a neimerzní situace, vliv na testy verbální fluence. Naše počáteční hypotéza je taková, že skupina v imerzním prostředí by měla mít lepší výsledky v L2 a horší v L1 oproti neimerzní skupině, co se týče fluence. Vzhledem k tomu, že verbální fluence je mimo jiné ovlivněna i pracovní pamětí, v práci je zařazen i test na pracovní paměť.

Propojením těchto dvou částí testování očekáváme, že výsledky Stroopova testu budou odpovídat těm z testů verbální fluence pro jednotlivé probandy i pro obě skupiny.

Klíčová slova: bilingvismus, kongnitivní funkce, exekutivní funkce, verbální fluence, imerze, výhoda bilingvismu, nevýhoda bilingvismu, inhibiční kontrola

APPENDICES

Appendix A: Language Experience and Proficiency Questionnaire

Dotazník o jazykových znalostech a zkušenostech

Vyplněním tohoto dotazníku souhlasíte se svou účastí ve výzkumu pro mou magisterskou diplomovou práci. Taktéž souhlasíte s tím, že všechny poskytnuté údaje jsou pravdivé a jsou poskytnuty dobrovolně. Osobní údaje jsou shromážděny a uchovány v rozsahu nezbytném pro naplnění účelu diplomové práce a zpracovány pouze v souladu s účelem, k němuž byly shromážděny. Nebudou zveřejněna žádná data, která by umožnila čtenáři identifikovat účastníky výzkumu.

Jméno		Příjmení		Dnešní datum	
Věk		Datum narození		Muž ☐	Žena ☐

(1) Uveďte všechny jazyky, které znáte, podle dominance (1 nejvíc → 5 nejmíň):

1	**2**	**3**	**4**	**5**

(2) Uveďte všechny jazyky, které znáte, podle pořadí osvojení (mateřský jazyk jako první):

1	**2**	**3**	**4**	**5**

(3) Prosím, uveďte, kolik procent času jste *v současné době průměrně* v kontaktu s těmito jazyky (*Součet uvedených procent musí dosáhnout 100%):*

Jazyk					
Procenta					

(4) Uveďte kultury, s kterými se ztotožňujete. Na stupnici od jedné do deseti ohodnoťte, do jaké míry se s kulturou ztotožňujete. (Například česká, kanadská, atd.):

Kultura					
Stupnice					

(Stupnice: 1 = nejméně, 10 = nejvíce)

(5) Kolik let formálního vzdělávání jste podstoupili? _____ Zaškrtněte nejvyšší úroveň vzdělání, které jste dosáhli.

☐ Střední škola s výučním listem
☐ Střední škola s maturitní zkouškou
☐ Vyšší odborné vzdělání
☐ Bakalářské vzdělání
☐ Magisterské vzdělání
☐ Doktorské vzdělání
☐ Jiné:

(6) V Kanadě ☐ studujete ☐pracujete ☐máte turistické vízum

(7) Máte problém se zrakem ☐, sluchem ☐, jazykovou poruchu ☐, poruchu soustředění ☐ či vývojovou poruchu učení *(*dyslexie, dysgrafie, dysortografie) ☐? Jestliže ano, napište, zda došlo ke korekci (např. dioptrické brýle).

(8) Jste pravák? Ano ☐ Ne ☐

(9) Bylo vám diagnostikováno psychické nebo neurologické onemocnění?
Ano ☐ Ne ☐

Anglický jazyk

Toho je můj Zvolte položku. jazyk.

(1) Věk, kdy…:

jste se začali učit AJ:	
jste začali ovládat AJ plynule:	
jste se přestěhovali do anglofonní země:	

(2) Uveďte, kolik let a měsíců jste strávili anglofonním prostředí:

	Počet let	**Počet měsíců**
v anglofonní zemi		
ve škole/ práci, kdy se mluví anglicky		
v anglicky mluvící rodině		

(3) Postoupili jste některý z mezinárodních standardizovaných testů jazykové způsobilosti v AJ (např. IELTS, TOEFL, CAE)? Pokud ano, jaká byla Vaše úroveň podle CEFR?

(4) Na stupnici od jedné do deseti vyberte úroveň svých jazykových dovedností v AJ:

Mluvení		Porozumění mluvenému slovu	
Psaní		Čtení	

(Stupnice: 1 = žádná, 2 = velmi nízká, 3 = velmi nízká, 4 = podprůměrná, 5 = průměrná, 6 = nadprůměrná, 7 = dobrá, 8 = velmi dobrá, 9 = výborná, 10 = perfektní)

(5) Na stupnici od jedné do deseti uveďte, do jaké míry následující faktory přispěly k vašemu osvojení AJ:

Interakce s kamarády		Samostudium	
Interakce s rodinou		Cestování	
Čtení		Sledování TV a YouTube	
Počítačové hry		Poslech písní	
Soukromé lekce AJ		Jiné	

(Stupnice: 1 = žádný vliv, 2 = minimální vliv, 5 = přiměřený vliv, 10 = nejdůležitější faktor)

Poznámky: …………………………………………………………………………