Adult sequential bilingualism and its impact on executive functions: a study on Russian – English bilinguals

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Abstract

The prevalence of bilingualism is continuing to increase in populations worldwide. The literature argues that bilingualism is associated with certain cognitive advantages, specifically in non-verbal tasks. Previous results consistently demonstrate that bilingual children score higher on non-verbal tasks when compared to monolingual children that speak the same language. The current study aimed to examine whether adults' bilingualism results in enhanced executive function (EF). Based on prior literature, it was hypothesised that there will be a significant difference in EF between monolingual and bilingual groups, favouring the bilingual group. A between-participants design was used to compare performance of Russian-English bilinguals (age 18-50 yrs, n = 45) with English speaking monolinguals (age 18-50 yrs, n = 49) (total N = 94) on three EFs (inhibition, switch function, and working memory). Participants completed the tasks in a single test session on a computer. A Mann - Whitney U test was performed to examine group differences on five computerised psychological tests of EF (Simon Task, Stroop Colour Word Task, Tower of London Task, Trail-Making Task and Wisconsin Card Sorting Test). The hypothesis was unsupported by the results, as there was not a significant between-groups difference on EF apart from on working memory. These findings highlight that bilingualism does not necessarily lead to improved EF when the second language is learned later in life. The implications of the findings from the current study, along with suggestions for future research, are raised in the discussion.

Declaration

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Introduction

1.1 Preamble

This thesis concerns adult bilingualism and the question of whether it confers an advantage on the executive functions (EF) in adults between 18 and 50 years of age. The research tested whether a bilingual group of participants would score higher on tests of executive functions then a monolingual group. Data on inhibition, shifting, and working memory were collected whilst participants performed specific tasks that required the use of these functions. Scores on the EF of bilingual adults whose first language was Russian and had acquired English as a second language at the age of 18 years or older were compared with those of monolingual English speakers.

1.2 Background: on language and bilingualism

'Language' is a symbolic system framed by specific rules and employed to convey meaningful messages to other users of the given language. The concept of a language covers various types of symbols, such as gestures, sounds and written characters that reflect ideas, actions, objects and events (Chao, 1968). As much as the science of mind has advanced over recent decades, questions still remain about the exact algorithms our brain deploys to process and implement language as well as about the neural circuits involved in achieving that purpose (Pulvermuller, 2002). In addition to the study of neural circuits, it is also important to consider how these processes are implemented in communication. At a more empirical and practical level, it seems reasonable to suggest that learning a second language sharpens one's perception of one's own and others' verbal patterns, grammatical structures and stylistic repertoire, thus improving overall communicative skills and creating new opportunities for the successful realization of one's personal potential. As immigration, global employment opportunities within multi-national companies, and the increased ease and affordability of travel increase, so does the need for individuals to speak and understand more than one language. The use of global forums like Facebook and other social media means that many people now have international connections, friends and acquaintances with whom they share common interests limited only by their ability to communicate with one another. Indeed, since language acquisition is closely linked to social interaction, social media provide an indispensable platform for learners to practice and refine their target language skills while taking part in spontaneous yet relevant conversations (or even verbal battles) with native users of the language as well as with other, possibly more advanced, learners.

To a certain extent globalisation has led countries and their peoples to improve their mastery of spoken and/or written speech. A recent survey conducted by a European Commission found that 66% of the world population consider themselves fluent in at least two languages. As many as 83% of Europe's population find learning foreign languages useful (European Commission, 2016).

1.3 Definition of bilingualism

The use of more than one language by an individual – child or adult – is usually referred to as bilingualism. It is a system where mastery fluctuates depending on the opportunity to use alternative languages and having exposure to other speakers of those languages (Hakuta, & Garcia, 1989). However, the scientific world provides various definitions of bilingualism ranging from a minimal level of proficiency to an advanced level of proficiency in both languages (Bialystok, Barac, Blaye, & Poulin-Dubois, 2010). At the higher end of the scale an individual communicates at a 'near-native' level. There is, however, a certain discrepancy within this definition. Individuals may consider themselves bilingual but only be able to produce speech in daily situations. Alternatively, they might only have mastered written language and can easily produce (write) and re-produce (read) written texts but fail to reach verbal fluency. These different modes of bilingualism are discussed next.

1.3.1 Natural bilingualism

Bilingualism can be reached through exposure from childhood to at least two languages used at home or elsewhere simultaneously. This is described as simultaneous or natural bilingualism (Bialystok, 2001; Sabourin, & Vinerte, 2015). It is often believed that children will grasp languages if they are simply exposed to them (Johnson & Newport, 1989). Yet, research demonstrates that to learn and maintain a second language children have to apply consistent effort and commitment and to receive creative reinforcement (Bialystok, et al., 2004).

Bilingualism subsumes a range of proficiencies and contexts. A young child starting school may be referred to as bilingual but it may be that she/he uses their language for familiar purposes and in the domestic context, yet another language may be their preferred language of communication outside these situations. A child may be monolingual at the time of starting school. A newly arrived immigrant child may be literate in a second language and be able to read and write to a certain extent, yet fail to communicate orally in the classroom setting. On the other hand, many children described as bilinguals might have three or even more languages at their command and it would be more correct to refer to them as multilinguals (National Association for Language Development in the Curriculum, 2011).

1.3.2 Sequential bilingualism

A person may become bilingual through studying a second language later in life, which is defined as sequential bilingualism (National Association for Language Development in the Curriculum, 2011). The incidence of sequential bilingualism is increasing worldwide. With more relationships and marriages between two individuals from different countries, more than one language is often spoken at home. For example, in Africa, it is not uncommon for people to speak up to five different languages at home. Although the literature has not documented precise statistics, the estimated proportion of African nationals who speak five or more languages, according to Baker (2001), is currently 60 to 75%. This number is expected to rise across the world over the next several years (Shin & Bruno, 2013).

When communicating with monolinguals, bilinguals, understandably, believe that sticking to one language is more effective. Conversely, bilinguals frequently use different languages to communicate to other bilinguals. This is not necessarily a speaker's attempt to show off or to look "fancy." Depending on the topic and the social context of a particular conversation, some words may sound better in one language than in another, be it for greater clarity, emotional nuances or enhanced understanding. Overall, switching between languages in a bilingual communicative act can serve as a useful strategy leading to variety of possible ends.

Learning to speak a second language is a skill that can be acquired at any stage in life. Sixty-five per cent of respondents tended to agree that language lessons at school is the preferred way of acquiring another language. A majority (64%) - considered the primary school years the most suitable age to start learning a second language, while 59% of respondents agreed that their language learning skills progressed the most in secondary school (European Commission , 2016). Nonetheless, acquiring an additional language is easier at a younger age because the brain is still developing and is more capable of learning (Johnson & Newport, 1989). This means that every component of the new language is more easily transferred to memory and becomes second nature through use and development. Additionally, the earlier learning of a second language often reduces an accent in oral speech. An accent is not an indication of the level of bilingualism. In fact, accents do not play a role in the level of proficiency in speaking a second language. As an example documented in the literature, researchers described a person with an English-Canadian background who moved to France where she learned to speak French, though she maintained an English accent when doing so (Dana-Gordon, Mazaux, & N'Kaoua, 2014).

1.3.3 Balanced versus unbalanced bilingualism

The concept of bilingualism encompasses a number of common misconceptions. One of the main misconceptions is that bilinguals have an equal level of language proficiency in all four macro-skills: speaking, listening, reading and writing, as well as knowledge of the cultures and national stereotypes essential for both languages. In reality, however, bilinguals usually use each of the two languages in different domains, such as home, school, work, and so on. This affects their use of language tools (e.g., sentence construction, vocabulary). Thus, there are two broad types of bilingualism: balanced and unbalanced. Each is dependent on the amount of vocabulary and the ability to read, speak, understand and write in the second language at a standard grammatical level. Sometimes a naturally bilingual child can speak fluently in two languages and without any accent but still be unable to write in one of the languages because his school program offers instruction in only one of those languages. Consequently, children who experience difficulty attaining proficiency in writing and reading the second language are categorised as unbalanced bilinguals. Conversely, balanced bilinguals are those who attain proficiency in the second language, both reading and writing it with competency. This difference is dependent entirely on the education of the child or adult.

1.4 Disadvantages of bilingualism

There are some disadvantages of bilingualisms. For example, learning a second language can interfere with communication in the first language. This means that previously learned words can be forgotten, thus making a conversation more difficult, or the speaker will have a difficult time using a given word in another language. One survey showed that the most commonly held belief among parents is that being bilingual slows down a child's development (Gollan, Montoya, & Werner, 2002). However, recent researches have found that language impairment is not a limitation for children because bilingualism and language impairment are unrelated (Bialystok, 2009). Therefore, removing a second language does not improve a speaking disorder or resolve issues with language delay.

1.5 Advantages of bilingualism: the executive functions

Some of the most commonly known advantages to being bilingual are those associated with cognitive benefits. Studies show that speaking a second language improves a range of cognitive skills such as attention and decision-making (Luk, & Bialystok, 2012; Bialystok, Poarch, Luo & Craik, 2014). Thus, being bilingual is useful for maintaining well-structured skills in communication, and should be encouraged and maintained in family settings where it will contribute to a child's development.

Evidence collected from a number of studies shows the constant need for bilinguals to selectively activate one language while suppressing the other and, plausibly, these processes improve the executive functions. Controlled by the frontal lobe of the brain, executive functions are referred to as the command system that directs the attention processes used for planning, solving problems and performing various other mentally demanding tasks. These processes include switching attention willfully from one thing to another, ignoring distractions to focus and hold information in the mind (Miyake, Friedman, Emerson, Witzki, Howerter, & Wager, 2000; Bialystok, 2015). Research done by one of the most influential researchers of bilingualism, a Canadian psychologist and scientist, Ellen Bialystok, has established that the bilingual brain simultaneously uses two languages, as both the mother tongue (L1) and the foreign language (L2) are active all the time (Miyake, et al., 2000). This suggests that since bilinguals constantly switch between two languages, they should also be better at switching between any two tasks. Other researchers have found that the bilingual brain has a better attention span and task switching capacities, which together improve working memory and inhibitory control (Bialystok, 2015; Jewsbury, & Bowden, 2016).

A crucial cognitive benefit of being bilingual, relates to the individual's improved cognitive flexibility. This advantage is expressed as the ability to create a variety of ideas and ways of coping with problems, along with the ability to skip quickly among sets of thoughts (Bialystok, Craik, & Luk, 2012). An American study confirmed that bilingual children adapt more quickly than monolingual children to changes and display enhanced awareness of their surroundings (Bialystok, Craik, & Luk, 2009).

If people learn another language, they also indirectly learn a way of looking at the world from a different perspective. Being bilingual opens up new worlds of global connection and understanding, and almost certainly allows some degree of flexibility in personal expression (Bialystok, 2015). A study conducted in Canada, showed that bilinguals pay closer attention to detail and have better verbal fluency (Shao, Janse, Visser, & Meyer, 2014). Their improved linguistic abilities come with the development of a strong cognitive flexibility (Bialystok, 2015).

Ongoing research on the bilingual advantage discovered that cognitive advantages strengthen throughout life and go on to reduce age-related cognitive decline (Schweizer, Ware, Fischer, Craik, & Bialystok, 2012). Bialystok's findings suggest that bilinguals have a later onset (4-7years on average) of dementia and Alzheimer's disease in old age than monolinguals (Bialystok, Martin, & Viswanathan, 2005).

This connection between language and neuro-regeneration supports the body of evidence that bilingualism contributes to cognitive reserve, which underlies slowing brain atrophy, associated with Alzheimer's disease (Bialystok et al., 2005; Bialystok, Craik, & Ryan, 2006). A significant number of researches on factors to combat symptoms of Alzheimer's disease (AD) and postpone their commencement have failed to consider environmental aspects. However, one of the identified environmental factors to delaying the onset of symptoms is exposure to a bilingual environment. This contributes to the 'cognitive reserve' and ensures that the brain operates at a higher level than that expected at certain levels of the disease. This conclusion is evidenced in the comparison of computed tomography scans of bilingual and monolingual patients diagnosed with AD who had the same level of education and the same level of cognitive performance.

Numerous studies claim that bilinguals demonstrate an advantage in executive function, such as shifting between tasks, mental set shifting, and inhibitory control processes. It is relevant to establish definitions of the subcomponents used in previous research. Executive function (EF) is the conglomerate of human cognitive processes responsible for the performance of complex mental activities and problem-solving tasks (Jurado & Rosselli, 2007). While aiming at the observation of people's behaviour in everyday situations, one must, nevertheless, establish EF as the research goal, despite EF and its development being currently under-explored. Three of the major components of EF are set-shifting, working memory, and inhibition. These have been under recent investigation and are the most relevant to the use of language (Jurado & Rosselli, 2007; Bialystok, Craik, & Luk, 2008b).

Set-shifting or switch function is an ability to switch between tasks or mental sets (Miyake et al., 2000). The investigation of set-shifting or switching predominantly includes grouping various tasks together representing the typical alternating runs paradigm, such as number-letter tasks or colour-shape tasks (e.g., Rogers & Monsell, 1995). It is involved when monitoring the language context and choosing the appropriate one, including monitoring conflict-behaviour and its minimisation through the inhibition of unwanted mental representations. It means that language switching and general task switching involve the same mechanisms (Prior & Gollan, 2011). Working memory is defined as a multi-component system with a large but finite capacity, which is responsible for maintaining information, its utilization and continuous processing (Baddeley, 2000). Inhibition is the ability to suppress irrelevant stimuli and focus attention onto stimuli that is important for the completion of a specific task (Philipp & Koch, 2009). Inhibitory processes may be particularly relevant to multilingual speakers, influencing the ability to switch between languages (Phillip & Koch 2009). The need to produce a word simultaneously activates lexical alternatives in both languages and triggers competition between them. To guarantee efficient choice of the language and to prevent interference between the languages, cognitive control functions must work effectively. This requires both inhibition of the language irrelevant to the situation and switching between languages (Luk & Bialystok, 2012).

1.6 Current study

A certain amount of research has suggested that learning a second language brings some cognitive advantage (Bialystok, Craik & Luk, 2008a; Calvo, & Bialystok, 2014). This suggestion is based on two main ideas: on the one hand, cognition is built around the central processing skills acquired through learning a second language where language is identified as one of the general domains indicating success in other domains. The process of cognition however, is not static and is prone to influence by lifetime experience, including the acquisition of languages (Bialystok, Craik, Grady, Chau, Ishii, Gunji, & Pantev, 2005). The majority of evidence, however, only captures only either the early childhood stage as executive function develops or later adulthood as the executive functions decline (Bialystok, et al., 2004).

Much research has been done on balanced bilinguals who acquire both languages from birth or dominant bilinguals who are more proficient in one language more than the other, while acquiring the second language in later childhood or adolescence. However, there is a vast number of dominant bilinguals who acquire the second language in young adulthood or later adulthood using pre-developed learning skills, educational background and formed national stereotypes and concepts. Despite the evidence that this type of bilingualism is common, the research on it is limited and requires further investigation. It was decided that including sequential bilinguals as the research participants would be scientifically relevant due to the lack of previous attention to them. In choosing the pair of languages among bilinguals it was noted that Russian-English bilinguals where Russian and English belong to completely different language groups, have not been the subject of previous research. Both these factors characterise the novelty of this research.

1.6.1 Aim of the current study:

The current study aims to explicate whether unbalanced Russian-English bilinguals demonstrate an advantage on the executive function. Measures of the executive functions of bilingual and monolingual participants will be compared. It is hypothesised that there will be a difference in executive functions between monolingual participants and bilingual participants favouring the bilingual group.

Method

2.1 Participants

N = 94 participants were recruited, *n* = 45 bilingual (*M* = 37.4, *SD*= 10.0 yrs.) and *n* = 49 monolingual participants (*M* = 36.6, *SD* = 10.32 yrs.). The first language for all bilingual participants was Russian and their second language was English. The bilingual participants were recruited from the Russian Community in Adelaide, SA, by the author who is a member of that community. Monolinguals, who were all English speakers, were recruited from the student body of the University of Adelaide and from among their friends and families.

2.2 Materials

Materials provided to the participants included an information sheet, consent form, and questionnaires comprised of demographic and language background questions (Appendices A-C). All materials were in English. A self-rated assessment of whether the participant considered him/herself to be bilingual and the level of proficiency in English language they considered themselves to have was required. This was followed by five computerised tests to measure executive functions: Simon Task (Simon & Rudell, 1967), Tower of London Task (Krikorian, Bartok & Gay, 1994), Trail Making Task (Army Individual Test Battery, 1944), Wisconsin Card Sorting Task (Nelson, 1976) and Stroop Colour Word Task (Stroop, 1992). The computerised tests were all programmed in Inqusit v4 (Millisecond Software, 2017).

2.2.1 Demographic information

The demographic component consisted of questions to determine age (in years), gender, level of education completed. This latter variable had five levels ranging from 'Did not complete secondary school' to 'Postgraduate qualification'.

2.2.2 The Simon Task

The Simon task (Simon & Rudell, 1967) is a measure of inhibitory control and presents participants with either a red or green circle on either the left or right side of the screen, and instructs participants to respond to the circle dependent on the colour (if the circle is red press the left SHIFT key, if the circle is green press the right SHIFT key; see Figure 1). In the congruent condition, the required response corresponds with the location in which the circle is presented, whereas the incongruent condition requires the response on the opposite side to where the circle is presented. Reminders are given for incorrect responses, to encourage participants to improve on previous attempts. There were 60 trials and the dependent variable was the difference in reaction time (RT) between incongruent and congruent stimuli.

Figure 1. The Simon Task (two examples: on the right show incongruent stimuli, and congruent stimuli on the left).

2.2.3 Tower of London Task

In this task (Krikorian et al., 1994), participants were required to move balls of various colours displayed on screen on three pegs into a goal sequence (see Figure 2). The goal was to move the balls one-by-one in order to match the goal sequence in the minimum number of moves possible. If the number of moves to complete the task were more than the required minimum, this attempt was considered failed; three trials for each problem were allowed. The score in this task was calculated as follows: three points are given for a problem for successful solution on the first trial; two points for successful solution on the second trial; and one point for successful solution on the third trial. A score of zero is given if all three trials are failed. The total score is the sum of points for all 12 trials. The Tower of London task was used as a measure of working memory (Krikorian et al., 1994).

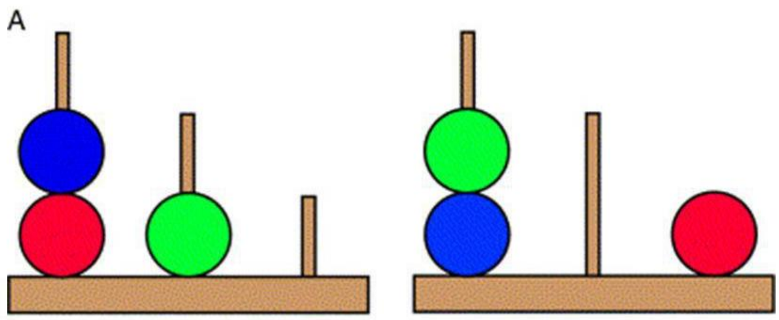

Figure 2. The Tower of London Task – the initial state on the left and the final state on the right; participants drag the balls, using the computer mouse.

2.2.4 The Trail Making Task

According to the Army Individual Test Battery (1944), the Trail Making Task (TMT) is neuropsychological instrument that provides information on a wide range of cognitive skills and can be completed in 1-2 min. The most widely used version of the Trail Making Task comprises two parts (Part A and Part B). In Part A, the participant uses a computer mouse to connect a series of 25 encircled numbers in numerical order (see Figure 3). In Part B, the participant connects 25 encircled numbers and letters in numerical and alphabetical order, alternating between the numbers and letters (see Figure 4). For example, the first number ‘‘1’’ is followed by the first letter ‘‘A,’’ followed by the second number ‘‘2’’ then second letter ‘‘B’’, and so on. The numbers and letters are placed in a semi-random fixed order, in such a manner as to avoid overlapping lines being drawn by the participant. The dependent variables are the total time to completion for Parts A and B. Part A is generally presumed to be a test of visual search and motor speed skills, whereas Part B is considered also to be a test of mental flexibility – the so-called switch function (Bowie, & Harvey, 2006).

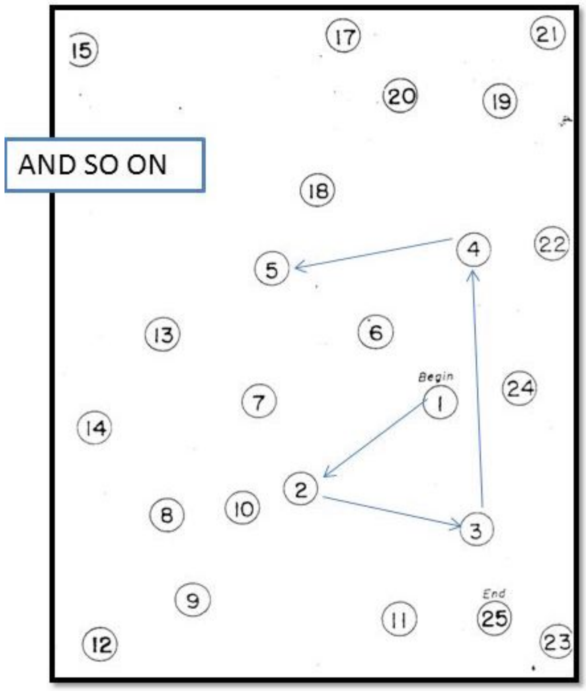

Figure 3. Trail Making Task part A, consisting of encircled numbers from 1 to 25 randomly distributed; the task is to connect the numbers in order in as little time as possible.

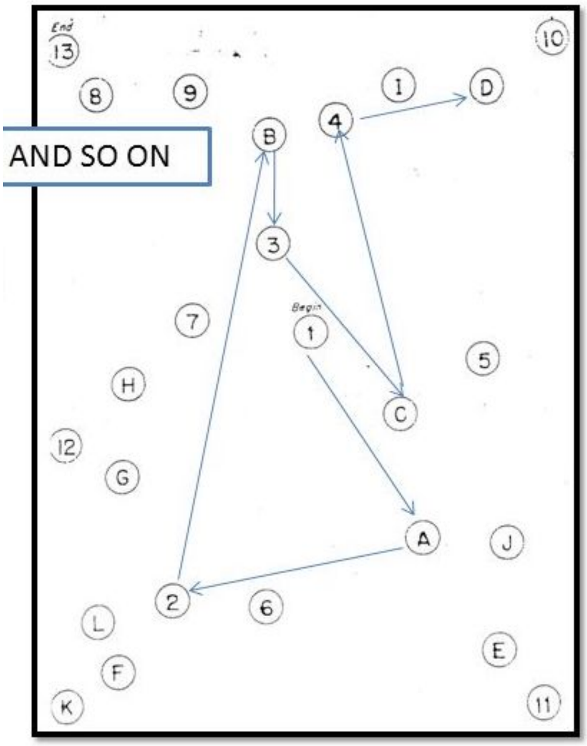

Figure 4. Trail Making Task part B, the task is to connect numbers and letters in an alternating pattern (1-A-2-B, etc.) in order in as little time as possible.

2.2.5 Wisconsin Card Sorting Task

The Wisconsin Card Sorting Task (WCST; Nelson, 1976) is a task designed to test cognitive shifting, in other words a switch function; that is, the ability to switch between tasks. In the Wisconsin Card Sorting Task, participants are asked to sort 128 cards into three categories (shapes, colours and number of symbols). Feedback is given as whether their decision for each card was correct. The rule for the classification of cards is changed every so often, thus testing the participant's ability to move forward in the task and inhibit or override the response from the previous classification. This tests whether the participant can adapt to a new rule in the task, without making errors, or continues to follow the rule of the previous category.

In the present study, four cards were presented on the computer screen (see Figure 5). The initial classification rule is not given to the participants and they have to begin sorting the cards in order to learn this themselves. There are four measures for this task. First, is proficiency on the task (categories achieved), second is the number of perseveration errors (the participant keeps applying the old rule in the trial), third is non-perseveration errors (when the participant does not apply the old rule) and the total number of errors (calculated by adding the number of perseveration and non-perseveration errors; see Nelson, 1976).

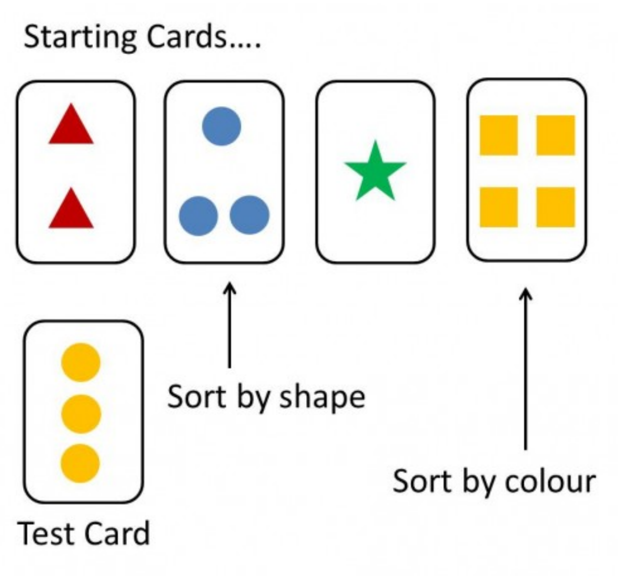

Figure 5. The Wisconsin Card Sorting Task (the Test Card at the bottom of the figure needs to be placed into the correct category by shape, colour or number).

It is expected that every participant will make mistakes, as it is not possible to know the classification rule on the first attempt. Instead, the aim of the Wisconsin Card Sorting Task is to learn by making perseveration errors. Perseveration errors only apply to blocks after the first block, as there needs to be a previous task for a participant to make perseveration errors. For the purposes of this study only errors were analysed because the number of categories achieved does not have sufficient variance in non-clinical samples.

2.2.6 The Stroop Colour Word Task

The Stroop Colour Word task (Stroop, 1992) is a measure of inhibitory control and presents participants with words in two colours, and instructs participants to respond by pressing either the left or right SHIFT key, depending on whether the word is displayed in blue or yellow.

If participants are responding to a word that is presented in the same colour as the name suggests (e.g., the word 'BLUE' is presented in blue), then the condition is congruent, meaning it does not require inhibitory control. On the other hand, the incongruent condition presents the word in in a different colour from what the name suggests (e.g., the word 'BLUE' is presented in yellow). Participants are instructed to respond to the colour of the word whilst attempting to ignore the meaning of the word itself. The instructions are to complete the task as quickly and accurately as possible. Whether the response is correct along with the time taken to respond was recorded. There were altogether 64 words presented on the screen in blue and yellow colours. The dependent variable was the difference in reaction time (RT) between incongruent and congruent stimuli.

2.3 Procedure

Participants were required to read the information sheet and provide informed consent prior to taking part in the study. Data collection took place at either the Psychology Computer Lab (room 230, Hughes) or at a location convenient to the participant, which was sufficiently free of distractions. Firstly, participants completed the demographic information. Secondly, participants completed the series of aforementioned tests on a computer: Simon Task, Tower of London Task, Trail Making Task, Wisconsin Card Sorting Task, Stroop Colour Word Task. The participants completed these five tasks consecutively in the above order without any breaks and altogether the tasks took approximately 15-20 minutes to complete, depending on the speed of the participant.

2.4 Ethical considerations

This study was approved by the School of Psychology Subcommittee of the University of Adelaide's Human Research Ethics Committee (number 18/18) (see Appendix D). Participants were informed that their responses were confidential and they would not be identified should the research be published. They were additionally reminded that their participation was voluntary and they were free to withdraw at any time, and feedback would be provided to those who wished to receive it.

2.5 Data Analysis

Histograms were plotted for scores on each of the executive function tasks for monolinguals and bilinguals separately (see Appendix E) and it was noted that the data were not normally distributed. As such, the Mann - Whitney U test was run as a non-parametric test to examine differences between-groups. The data were analysed using R (R Core Team, 2018).

To deal with the presence of extreme RTs on the Stroop Colour Word and Simon tasks (where participants took up to seconds to respond) the RT distributions were Winsorized at 10% (Wilcox, 2012). Winsorizing the distribution allows robust protection against outliers, because it effectively cuts the largest and smallest values from the data set, thereby giving a more reliable and unbiased estimate of the central tendency. It is reported that ten percent is a suitable winzorisation for each tail of the distribution (Wilcox, 2012). This technique was applied for data from the Simon and Stroop Colour Word tasks and then the mean and median differences between the Winsorized distributions, were calculated.

Results

The following section presents the findings of the current study, with the primary aim of comparing the measures of the two groups on each task. Table 1 gives an overview of participant characteristics in both the monolingual and bilingual adult samples, including mean age, gender proportions, and highest level of education. The level of education variable had five levels from 'Did not complete secondary school' to 'Postgraduate qualification' but only four of them were needed. Table 2 shows the means, standard deviations, medians, and the effect size for the differences between groups (monolinguals vs bilinguals).

Table 1

Characteristics of monolingual and bilingual participants (N = 94) including age, gender, and highest level of education

	Monolingual adults (n = 49)		Bilingual adults (n = 45)	
Age (yrs), Mean (*SD*)	36.6	(10.3)	37.4	(10.00)
Female (*n*)	30		16	
Male (*n*)	19		29	
Highest level of education (*n;* % in parentheses)				
Completed year 12	8 (16.3%)		4 (8.9%)	
Certificate/Diploma	15 (30.6%)		11 (24.5%)	
Bachelor degree	22 (44.9%)		14 (31.1%)	
Postgraduate qualification	4 (8.2%)		16 (35.5%)	

Table 2

Descriptive statistics summarising participant scores on the five executive function tasks by group, means, standard deviations, medians and the effect size (monolinguals vs bilinguals)

		M (SD)	*Median*	*M (SD)*	*Median*	Cohen's *d*
		Monolingual		Bilingual		
Simon Task [a]		15.3 (66.8)	22.0	40.3 (89.7)	21.4	-.32
Tower of London	Score	30.1 (6.08)	31.0	32.2 (5.20)	33.0	.36
TMT (sec)	Part A	52.5 (25.9)	42.9	56.5 (24.8)	54.7	-.16
	Part B	72.4 (45.9)	57.6	78.6 (46.1)	72.5	-.13
WCST	Total Errors	29.7 (16.8)	29	31.6 (19.2)	26	-.10
	Perseveration Errors	7.8 (3.76)	7	7.9 (4.66)	7	-.02
Stroop Colour Word Task [a]		36.9 (103.2)	17.8	52.4 (66.9)	33.1	-.17

Note: [a] Reaction time differences measures in milliseconds; Cohen's *d* – standardised difference between means, where negative values indicate better performance in the monolingual group

3.1 Simon Task

The results of a Mann - Whitney U test showed that there was no significant difference in reaction time differences between the two language groups on the Simon task (z = 0.68, p = .497). The hypothesis was not supported. Figure 6 shows a box-plot of performance on Simon Task.

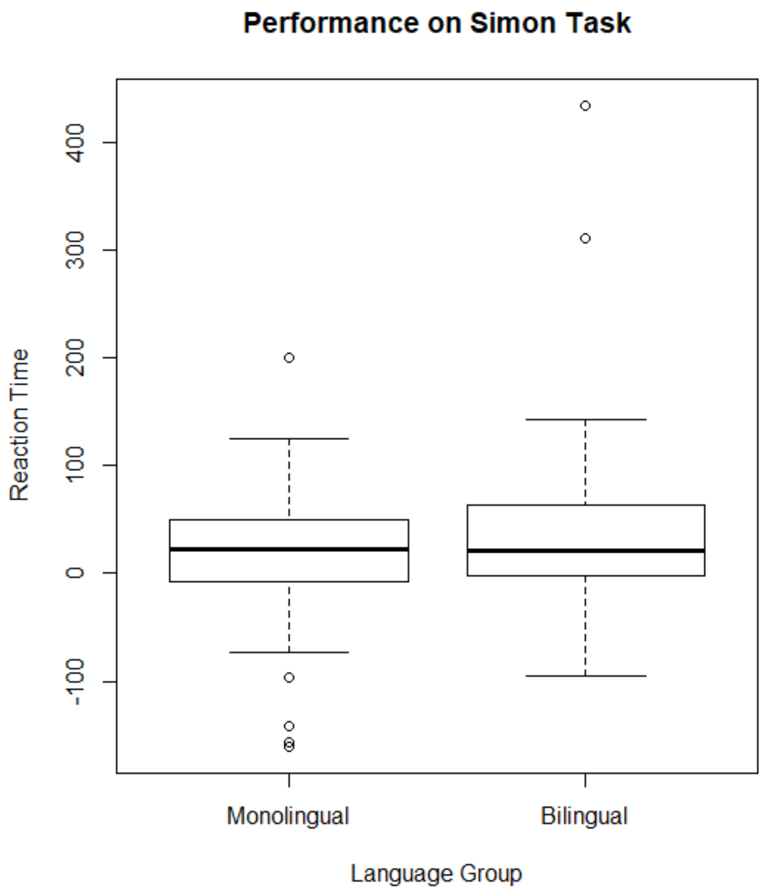

Figure 6. The difference in reaction time on the Simon Task between monolingual and bilingual participants

3.2 Tower of London Task

The results of a Mann - Whitney U test showed that there was a significant difference in task performance between monolinguals and bilinguals, (z = 2,42, p = .035), favouring the bilingual group. The hypothesis was supported for this task; the magnitude of this effect was small-to-medium (d = 0.36).

3.3 Trail Making Task

The results of a Mann - Whitney U test showed that there was no significant difference in completion times between the two language groups for either Part A ($z = 1.16$, $p = .249$) or for Part B ($z = 0.12$, $p = .908$). Furthermore, the magnitude of the effect between-groups was negligible on both parts of the test. The hypothesis was not supported. Figure 7 and 8 show the box-plots of outcome of Trail Making Task Part A and Trail Making Task Part B, respectively, between the two language groups.

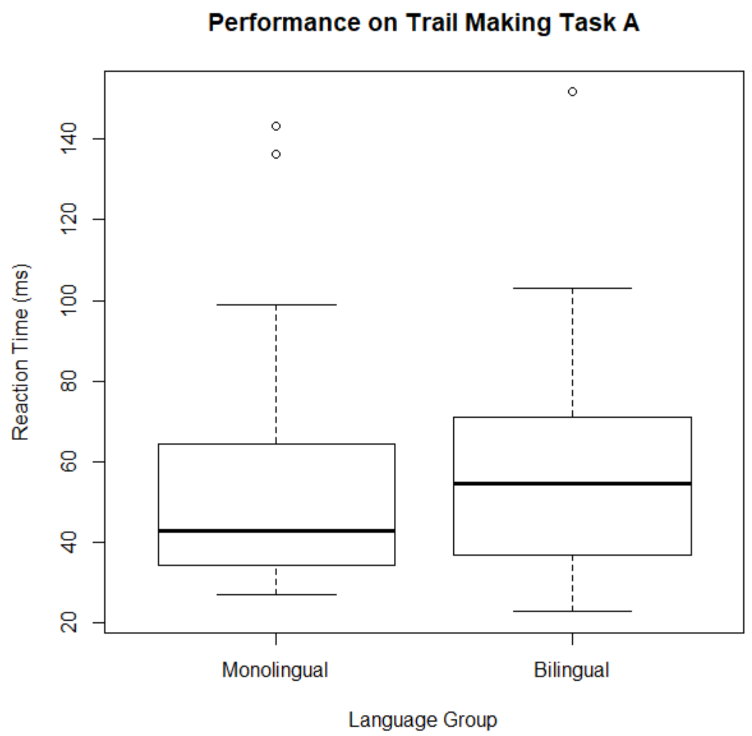

Figure 7. The difference in completion time on Trail Making Task part A between monolingual and bilingual participants.

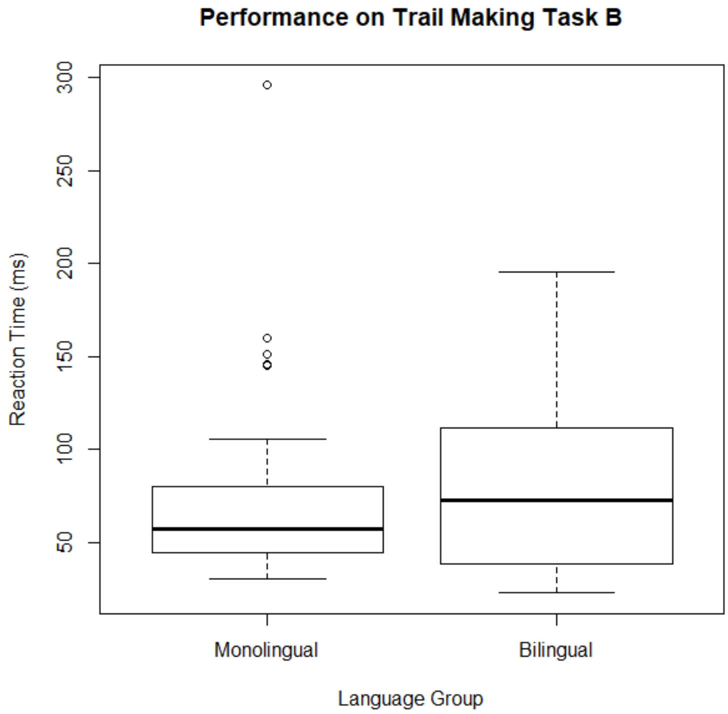

Figure 8. The difference in completion times on Trail Making Task part B between monolingual and bilingual participants.

3.4 Wisconsin Card Sorting Test (WCST)

The results of a Mann - Whitney U test showed that there was no significant difference between the groups on the WCST with a negligible effect size in both the total numbers of errors ($z = 0.33$, $p = .743$) and perservative errors ($z = 0.26$, $p = .794$). The hypothesis was not supported. Figures 9 and 10 show the box-plots of outcomes of the total amount of errors and perservative errors, respectively, between the two groups.

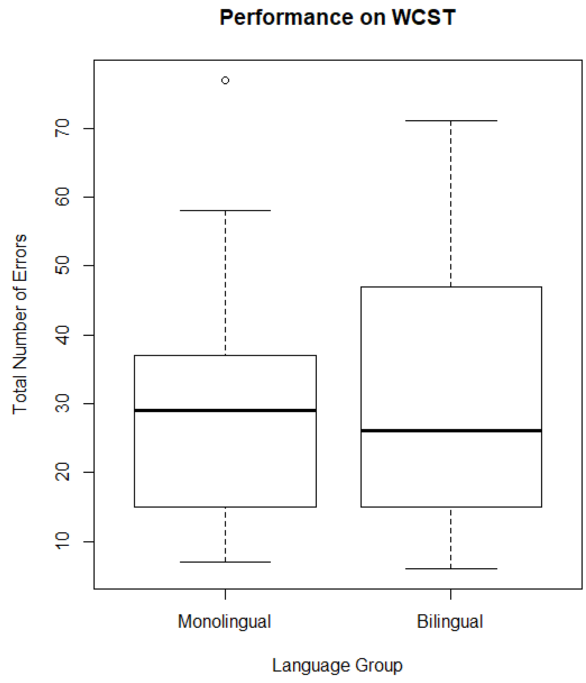

Figure 9. Median difference in total numbers of errors between the two language groups on the WCST.

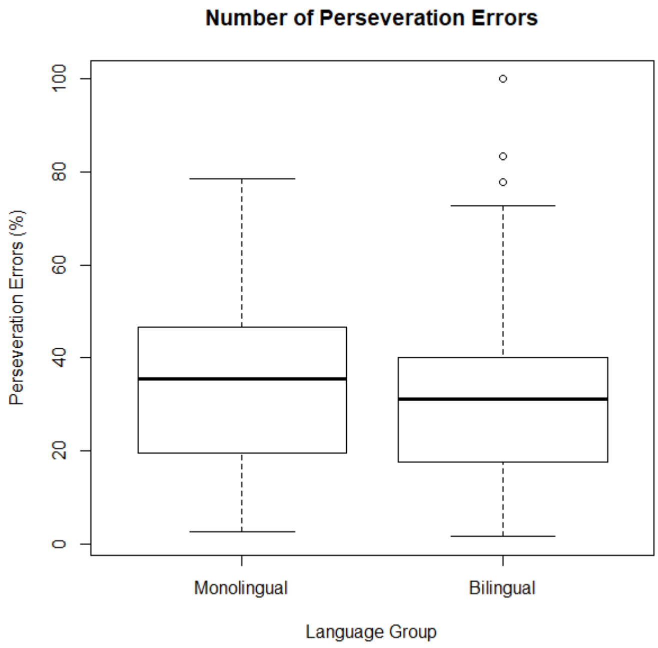

Figure 10. Median difference in numbers of perseverative errors between the two language groups on the WCST.

3.5 Stroop Colour Word Task

The results of a Mann - Whitney U test showed that there was not a significant difference in reaction time differences between the two groups on the Stroop Colour Word Task (z = 1.62, p = .106). The hypothesis was not supported. Figure 11 shows a box-plot of performance on Simon Task.

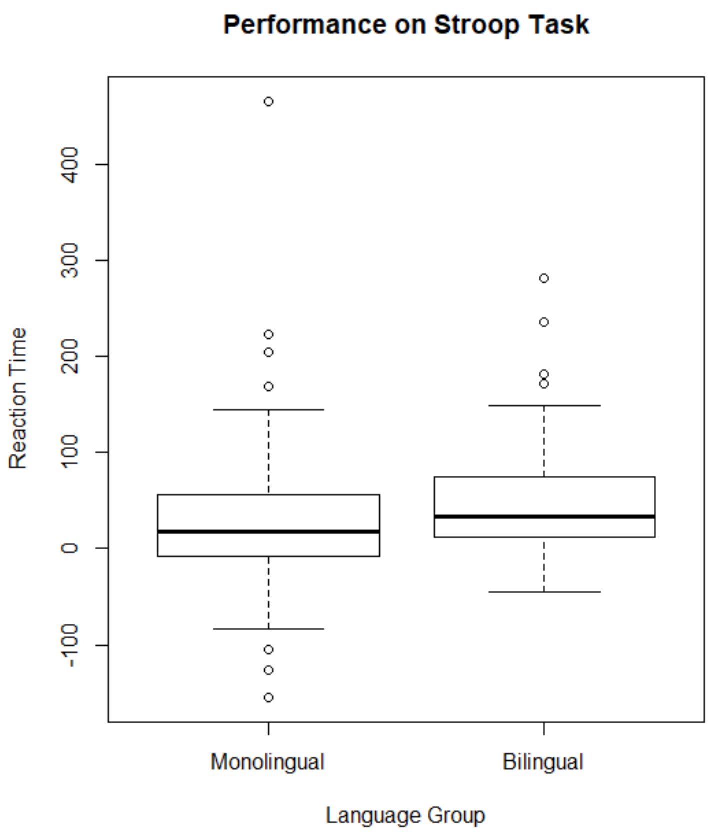

Figure 11. The difference in reaction time on the Stroop Colour Word Task between monolingual and bilingual participants.

3.6 Participant's level of education

Pearson's Chi-squared test was used to assess whether there was any difference in education levels between groups, which might have affected the outcomes reported so far. There is a significant difference between groups, $X^2(3)=10.78$, p= .013; the bilingual group have more postgraduate qualifications than the monolingual group. Table 3 shows both actual and expected numbers in each group at each level of education. This difference could arguably be expected to have biased results in favour of the research hypothesis that bilinguals would perform better on tests of EF.

Table 3

Expected and actual numbers of participants in each group by level of education

	Monolingual (n = 49)		Bilingual (n = 45)	
	Actual	Expected	Actual	Expected
Completed year 12	8	6	4	5
Certificate/Diploma	15	13	11	12
Bachelor degree	22	18	14	17
Postgraduate qualification	4	10	16	9

Discussion

4.1 Study overview

This study investigated unbalanced sequential adult Russian-English bilingualism and its impact on performance in tests on executive functions. To examine the effect of second language acquisition on executive functions we recruited two groups of participants: monolingual and bilingual adults ranging from 18 to 50 years of age. The target groups were defined in accordance with strict criteria where Russian-English adults acquired their second language at a mature age and had lived in Australia more than five years. They were also unbalanced bilinguals as opposed to those bilinguals whose second and first languages were acquired simultaneously. The purpose of research was to study if a bilingual group of participants would obtain a higher score in tests of executive functions than a monolingual group. Scores on EF of bilingual adults were compared with those of monolingual English speakers. The findings were further interpreted and analysed and presented in this study. In the present study, we have examined five psychological tests of EF: two of these tests measured inhibitory control (Stroop Colour Word Task and Simon Task), two tests measured switch function (Wisconsin Card Sorting Task and Trail Making Task), and one test measured working memory (Tower of London Task).

4.2 Summary of findings

The hypothesis that there will be a significant difference in executive functions between monolingual and bilingual groups favouring the bilingual group was not supported. It was found that there was not a statistically significant difference in executive function between monolingual and bilingual adults on the Simon Task, Stroop Colour Word Task, Wisconsin Card Sorting Task, and Trail Making Task; however, a statistically significant difference was observed on the Tower of London Task (ToL), which measures working memory. Both groups scored similarly on all measures ($p > .05$) apart from ToL ($p = .035$). This indicated that in this sample speaking an additional language beyond one's native does not lead to an advantage in executive functions, or in other words, does not have any effect on some EF such as inhibition and switch functions, but there is some effect of being bilingual on working memory. The data was analysed to determine whether the two groups were optimally matched. A Chi-squared test was run to examine if our two groups of participants were matched on education level. Estimated and actual numbers from each group were compared. Estimated numbers reflect researchers expectancy that belonging to a particular group of participants does not depends on the education level.

The result shows that groups of participants were statistically different from each other on education level (there are more highly educated bilingual participants). Despite that, bilinguals' performance in all tests demonstrated no difference from the group of monolinguals with only a small difference on working memory performance.

4.3 Findings in context of past research

The findings are consistent with a meta-analysis published earlier this year (Lehtonen, Laine, Jarvenpaa, Soveri, & Bruin, 2018). Lehtonen and colleagues have conducted a meta-analysis of 152 studies of adults with six executive function domains, comprising 891 effect sizes. It was found that there was no support for the hypothesis that bilingualism is associated with increased executive functioning in adults. Therefore bilingual adults do not have the supposed bilingual advantage in executive function of the cognitive control system.

Although the popular media and education authorities have accepted the hypothesis that bilingualism is associated with enhanced executive functioning, the psychological literature has previously recognised that the issue is controversial, with some studies having null results, and others mixed results (Lehtonen et al, 2018). Lehtonen et al. (2018) point out that there has been previous publication bias in this field of research, with studies that did not confirm the bilingual enhancement hypothesis being less likely to be submitted for publication, or published (Lehtonen et al., 2018). However, since around 2014, this trend may have been reversed, with studies critical of the bilingual enhancement hypothesis being published (Hilchey & Klein, 2011; Paap & Greenbery, 2013; Lehtonen et al., 2018).

Lehtonen et al. (2018), report that previous meta-analyses of the bilingual enhancement hypothesis data have yielded mixed results. The previous meta-analysis by Paap, Johnson, and Sawi (2015), for example, found that only a small proportion of studies supported the hypothesis, as was with the studies by Bruin (2015), Donnelly (2016), and Grundy and Trimmer (2016) (Lehtonen et al., 2018). This situation led Lehtonen et al. to conclude from their own meta-analysis that "the evidence regarding the bilingual advantage is inconclusive and controversial" (Lehtonen et al., 2018, p. 4).

In general, previous studies failed to show that there is an aspect of executive function where bilinguals consistently and systematically show significant advantages over monolinguals. Usually studies taken to support the bilingual enhancement hypothesis show an advantage in one task only (Lehtonen et al., 2018) as found in the current study. Previously, better results for bilinguals at working memory performance were reported (e.g. Baddeley, 2000), which consistent with our results.

The meta-analysis by Lehtonen et al. (2018), unlike many previous studies, examined a multitude of executive function components, including monitoring, shifting, inhibitory control, verbal fluency and attention (Lehtonen, et al., 2018). There was also a more comprehensive data base, with 152 peer reviewed published studies, 29 doctoral theses, 13 other theses (presumably MA and Honours theses), and four non-peer reviewed studies, making this the most comprehensive study available at the time of writing (Lehtonen et al, 2018).

After correcting for publication bias, it was concluded by Lehtonen et al., that there was no evidence for a bilingual advantage in any of the examined components of executive function

(Lehtonen et al., 2018). The present study offers further evidence that the bilingual enhancement or advantage hypothesis is not confirmed.

What could be the reason for this failure of confirmation of a popular psychological thesis held by education authorities? Bialystok (2017), although not directly addressing this question, does shed some insights, for example, even if there were reasons to suppose that bilingualism confers cognitive *advantages*, these may be negated by the cognitive *costs* of bilingualism, such as competition for selection and joint activation in bilinguals, requiring selection to prevent possible interference and confusion (Bialystok, 2017). Whether this is the case will require further research.

Across many studies in the field, findings support only a weak bilingual advantage on executive functions, and researchers could therefore be overestimating the bilingual advantage (Luk, De Sa, & Bialystok, 2011; Cox, Bak, Allerhand, Redmond, Starr, Deary, & MacPherson, 2016). The literature argues that an unbalanced bilingual population demonstrates certain advantages with regard to inhibitory control (Bialystok, 2001; Bialystok, et al., 2004). In particular, a study that measured inhibitory control in an unbalanced bilingual population reported that the bilingual participants scored high on the Stroop Colour Word Task and the Simon Task (Heidlmayr, Moutier, Hemforth, Courtin, Tanzmeister, & Isel, 2014). Another study done by several researchers made progress in conducting an experiment free from bias factors, and claimed that bilingual outperformed monolingual on executive control tasks (Sabourin, & Vinerte, 2015; Ratiu, & Azuma, 2015). However, in this research no evidence was found to support that hypothesis.

The present study comprised an older sample of bilinguals (aged 18-50 yrs; M= 37.0 yrs). The sample age was determined by the critical period for language learning, which states that children who study a second language from early childhood demonstrate an advantage in regard to inhibitory control, working memory and a switching task (Bialystok, Barac, Blaye, & Poulin-Dubois, 2010; Bialystok, 2010). Consequently, the present study aimed to investigate whether these results are applicable to older populations of unbalanced bilinguals. The results obtained for the majority of tasks suggested that bilingual people do not show a higher level of performance in comparison to the monolingual group; this in return suggests that the age of language learning (or the second language acquisition) is not a key factor determining performance on EF. This study successfully corroborates the recently published meta-analysis findings (Lehtonen et al., 2018).

There have been theoretical presuppositions for a bilingual advantage in EF, although it is documented that this may be due to publication bias, where in other words, researchers might prefer to publish only positive results of their studies (Lehtonen et al., 2018). Thus, the data revealed a significant correlation between the sizes of the effect, although these results may be slightly biased, since null (or negative results) are not reported as often. This can be the reason for the many small effects reported in the literature examined by the meta-analysis, when exploring previous research on the association between bilingualism and EF.

Along with publication bias, the sample size is another important consideration. A potential bilingual advantage has been argued in more detail in studies with smaller sample sizes, while this was not the case for studies with large sample sizes.

The current body of literature dedicated to EF in bilinguals' performance versus monolinguals' performance provides predominantly compelling evidence to support bilinguals' advantage. However, the most recent findings have failed to report the same result and argue that the bilingual advantage is largely overestimated due to lack of supporting evidence (Paap & Greenberg, 2013). Besides, the previous body of research predominantly involved respondents among natural bilinguals and their EF performance of the three major EF subcomponents (inhibition, working memory and switch function).

4.4 Significance

The findings in the present study do not allow the drawing of definite conclusions. For example, it was found that some executive functions, such as working memory, were influenced by being bilingual, which shows that it is possible that other areas of the brain could be affected.

Therefore, this emphasises the importance of further investigation on working memory performance.

Furthermore, it is important to take into consideration whether the participants are unbalanced or balanced in the second language. It can be suggested that sequential bilinguals are need to learn a second language and to be able to achieve this, the bilinguals perform at the same level as monolingual speakers. However, the current study did not find a significant difference between the performance of monolinguals and bilinguals on EF tasks. This suggests that skills in executive functions are not the main factor affecting the performance scores from these tasks for bilingual speakers. This could be determined by the fact that the participant are already well educated, and it means that future research should investigate other possible explanations for the similarity in scores. While collecting the data from Tower of London test there was an awareness that there were certain technical issues with the way the computer mouse worked, but nonetheless there is no reason to believe that these will systematically favour the bilingual people; regardless of the nature in technical issues, the error in the test condition would equally affect both groups but the results still may not be robust.

In this study, the focus was on Russian - English bilingual adults. However, it is important to consider that bilingual adults proficient in a different language could demonstrate increased or decreased performance on executive function. The Russian and English languages belong to different language groups and, accordingly, involve different syntax and morphological patterns to be processed by the brain. Thus, in the Russian language it is particularly expressed in the use of various prefixes and suffixes to convey the speaker's attitude to the subject, insert additional meaning or create synonyms and antonyms. Flexible word order in the Russian sentence is explained by word endings. It allows Russian speakers to guess the word meaning through the morphemic system in cases where the word did not exist before and is customised to an instant context. Nevertheless, considering that this study did not include participants proficient in other languages (e.g. Chinese or Afrikaans), it is not possible to draw the same conclusion. If participants were bilinguals in languages belonging to the same language group, the results may have been different as the syntax and morphology would involve the same processes to grasp the meaning and convey it in the language tools, for example, bilinguals in English and German or English and Dutch.

Further, this study recruited unbalanced bilinguals who were less proficient in reading and writing and more fluent in speaking and understanding. It is relevant to indicate that further studies of the performance of balanced sequential bilinguals might yield results demonstrating whether being balanced or unbalanced has an effect on executive function.

4.5 Limitations

It is thought that, at the stage of data collection, there may have been technical issues, which affected the results due to experimental noise. Further, as other tests did not show a significant between-groups difference, it is concluded that the results of the statistical analyses on ToL are not reliable for this particular task.

Another limitation faced during this research is the choice of psychological tests to measure executive function. Current studies have predominantly focused on unbalanced bilingualism, and although there is an existing body of literature in this area (Rosselli, Ardila, Lalwani, & Vélez-Uribe, 2016), there is a lack of language proficiency for some bilingual participants. One of these is an additional measure of reading speed. Reading speed has been identified as a confound in the Stroop Colour Word Task, which means that it could influence the results (Coderre, Heuven, & Conklin, 2013).

The order of completion for the tasks could also have affected performance. The first task participants completed was the Simon Task, followed by the Tower of London Task, Trail Making Task, Wisconsin Card Sorting Task, and finally the Stroop Colour Word Task. The first task was three minutes in duration and due to time constraints participants were under pressure to complete the task. Respondents to be the first to complete the Simon Task could have experienced boredom due to the relatively low level of cognition needed to complete the task. It is plausible that this would have led to decreased performance on the remaining tasks. This may have impaired the participants' conduct and is explained by additional pressure for the participants, represented by a significant loss of concentration, enthusiasm, and interest in proceeding with the remainder of the test. On the other hand, if participants were presented with the Tower of London task first, which did not have any time pressure and was not long in duration, and then participants could have better maintained their focus for the duration of the whole experiment.

The second task was the Tower of London Task (Krikorian, Bartok & Gay, 1994), which did not have time constraints, and therefore was less stressful. However, the program had some technical issues. The computer mouse control did not work properly; the task for this test was to move the balls appearing on the screen, and when the participant attempted to move the ball, the picture of the ball temporarily disappeared from the screen. Even though it was confusing for the participants they successfully dealt with this problem. As both groups faced the same problem on this task, it is proposed that this issue did not affect the validity of the present study, due to the fact that all participants were set with the same conditions that did not favour either of the groups in particular. The Tower of London Task did not measure the time required to complete the task so participants could solve it in their own time, yet the potential loss of concentration after the first task could presumably have affected the conduct of participants.

In comparison to that, the Trail Making Task was short and engaging, and therefore considerably more interesting to participants. It required them to perform these tests with the maximum speed and accuracy with only 1-2 minutes for completion. Due to the short duration, it was easier for respondents to operate.

The Wisconsin Card Sorting Task is a study of switch function. However, participants may have found it frustrating because the task requirements were not explained clearly enough. Respondents tended to express feelings of irritation if they committed perseverative errors because they had difficulty with problem solving and identifying the correct rule for each category. Non-significant results were obtained for both the Trail Making Task and Wisconsin Card Sorting Task results. Thus, the bilingual advantage seems unlikely, since both groups showed similar performance.

It is argued that the age of acquiring a second language has little effect on inhibitory control, the Stroop effect largely depends on the colour of the words and its meaning; since the monolingual could recognise the meaning faster (as the meaning of the words was on their first and only language), it should interfere with colour and affect the performance. On the contrary, bilingual participants should score higher on the Stroop Colour Word Task, as the meaning of the word is part of their second language. However, both groups showed similar results, and this could be due to the fact that participants were utilizing a strategy which does not require attention on the word or its meaning. Rather, participants often have a tendency to focus their attention directly above the presented word, so that the colour is the main focus and the word does not interfere with the response. This can improve performance on the task, and minimize the Stroop effect in both groups, regardless of the number of languages that a person can understand. It also suggests that adult people are flexible in inhibitory control tasks, and can adapt their approach accordingly, to improve their performance.

Poor match of both participants groups in their educational background may be considered as an additional limitation for a thorough comparison. Participants in the bilingual group all had completed higher education at the Bachelor degree level or higher, while participants in the monolingual group had a lower level of education. The single difference in performance of bilinguals and monolinguals captured in the test on working memory as opposed to lack of such evidence in other tests may be explained by certain skills in bilinguals developed during formal study which inevitably triggers such skills as time-management, organisation, decision-making, overcoming obstacles, self-motivation, confidence and problem-solving. Therefore, it is impossible to draw the conclusion that better results in the test on working memory evidence advantages in the bilingual group. Therefore, this suggests that further research should involve respondents with a better matched background to eliminate such limitation to interpretation of results. At the same time, bilingual group was not even in mastery of their macro-skills in the second language: some respondents were stronger in their passive macro-skills (reading and listening) and weaker in active ones (writing and speaking), while other respondents successfully mastered speaking but their listening macro-skills were not as strong. Such uneven development may be explained by the fact that the majority of bilingual respondents obtained their higher education overseas, accordingly practise of the second language mostly relied on receiving information, rather than producing written texts.

Finally, the testing environment itself could have been improved for some participants, to limit the number of distractions, such as background noise. An environment, which enables participants to complete the tasks without background noise may have improved their ability to concentrate. However, this is often difficult to address due to time constraints. Addressing the study design flaws in the future will improve the assessment of executive control and help to obtain a more informed understanding of whether bilingual advantage exists in the tasks of executive control.

4.6 Suggestions for further research

After performing this study on bilingualism, it was noted that previous research demonstrates advantages on working memory (WM) performance for bilingual speaking adults (Ratiu, & Azuma, 2015); however, there is a significant lack of studies on WM performance in bilinguals as opposed to monolinguals. Besides, the present study tested unbalanced bilingual participants rather than balanced respondents who are so widely represented in other studies. In the present study, were examined five tests; two of these tests measured inhibitory control (Stroop Colour Word and Simon Task), two tests measured switch function (Wisconsin Card Sorting Task and Trail Making Task), and only one test (Tower of London) measured WM. From the results, the following recommendations can be made. It is suggested that future research use a different test from the Tower of London Task to assess WM. Future research should equally recruit both unbalanced and balanced bilinguals; to attain an understanding of whether lacking full proficiency in a second language has a significant effect on EF, and in particular on WM performance. It is also important to control the trial length when conducting studies of this nature. Besides, respondent groups should be thoroughly matched in their educational background to eliminate a potential effect of skills acquired in previous schooling. A specific mastery level for the second language should also be set for the bilingual participants to establish that all four macro-skills in the language proficiency are equally developed.

Since inhibitory control is a well-studied skill in EF and the comparison between monolinguals and bilinguals was the topic, further research in this area is no longer a necessity. Although this study did not find any advantages for bilingual adults compared to monolingual, the question remains under consideration in the existing literature. A meta-analysis (Lehtonen et al, 2018) refers to a controversy with studies in which mixed results are published and monitoring the size of the sample in future studies could help resolve this problem and give a clearer idea of whether bilingualism is associated with higher performance for tasks requiring EF skills. The studies carried out here have not found a bilingual advantage on either the Trail Making Task or the Wisconsin Card Sorting Task. This is seen in the interpretation of results, which demonstrate that the effects were smaller for bilinguals when compared to monolinguals. No further research can be suggested to examine the same area of the switch function. Findings in WM function, however, require additional testing.

One of the philosophical and methodological issues raised by this field of research is whether there is circularity involved. People may already have superior executive functions prior to learning the second language, rather than the acquisition of the second language itself leading to an increase in levels of EF. In consequence, there needs to be a detailed theoretical examination of the assumptions and interrelationships in this field of research (Cox, Bak, Allerhand, Redmond, Starr, Deary & MacPherson, 2016).

Other questions, which need an answer, include: What is the connection between neurological levels and the hypothesized increase in the efficiency of cognitive functioning? Why did the researchers think there should be a connection? Is there a neuro-theoretical reason why there should be a connection between the language center of the brain and the spatial center, given that these are different areas of the brain? Does cognitive neuropsychology know enough about the functioning of the human brain to answer these questions? If they don't, why do these areas of research remain unexplored?

Even if learning another language does result in an improvement in cognitive functioning, is there anything special about language itself, which could generate this result? Could the same, or a greater increase in cognitive functioning be achieved by (1) a deeper understanding of the first language, that is at an advanced level of literature study and writing, or (2) by the study of mathematics and/or music which are known to develop cognitive skills?

4.7 Final conclusion

Bilingualism, the acquisition and understanding of two languages, weakly affects EF. Much of the literature to date has explored the relationship between bilingualism and various aspects of EF, mainly focusing on inhibitory control, and the working memory performance and switch function. Monolingual and bilingual participants have been compared using tasks that measure these skills. The results show that bilingual participants did not outperform monolingual participants, the effect sizes obtained were relatively weak and, therefore, did not produce sufficient evidence of a bilingual advantage.

In the literature addressing this area of research it is asserted that this lack of evidence can be associated with conflicting information between the two languages. Nevertheless, it is important to understand that although limited language proficiency is associated with unbalanced bilingualism, this has not yet been confirmed as either an advantage or disadvantage to EF. Given that bilingualism is associated with higher scores on working memory, it can be said that productivity is largely dependent on the task used to measure EF and how it affects the cognitive process.

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Appendices

Appendix A. The Consent form.

THE UNIVERSITY *of* ADELAIDE

Human Research Ethics Committee (HREC)

CONSENT FORM

1. I have read the attached Information Sheet and agree to take part in the following research project:

Title:	**Bilingualism and Executive Functions**
Ethics Approval Number:	[redacted]

2. I have had the project, so far as it affects me, and the potential risks and burdens fully explained to my satisfaction by the research worker. I have had the opportunity to ask any questions I may have about the project and my participation. My consent is given freely.

3. Although I understand the purpose of the research project, it has also been explained that my involvement may not be of any benefit to me.

4. I agree to participate in the activities outlined in the participant information sheet.

5. I understand that I am free to withdraw from the project at any time.

6. I have been informed that the information gained in the project may be published in an Honours thesis and journal article

   I have been informed that in the published materials I will not be identified and my personal results will not be divulged.

7. My information will only be used for the purpose of this research project and it will only be disclosed according to the consent provided, except where disclosure is required by law.

8. I am aware that I should keep a copy of this Consent Form, when completed, and the attached Information Sheet.

Participant to complete:

Name: _____________________ Signature:________________________ Date: __________

Researcher/Witness to complete

I have described the nature of the research to ____
(print name of participant)

and in my opinion she/he understood the explanation.

Signature: __________________ Position: _________________________ Date: __________

Version 01 Date: Tuesday, 13 March 2018

Appendix B. The Demographic questionnaire

Demographic questionnaire

ID: ________

I . What is your gender?

1. Female

2. Male

3. Other/Rather not say

II. What is your age (yrs)?

____

III. What is the highest level of education you completed?

1. Did not complete secondary school

2. Completed year 12

3. Certificate or diploma

4. Bachelor degree

5. Postgraduate qualification

IV. Do you consider yourself bilingual?

1.Yes (go to the next question)

2. No (go to the question **VI**)

V. How long have you been speaking English as a second or other language?

1. less than 5 years

2. 5 years or more

VI. Would you like to receive a summary of the results of our study?

Yes (please provide your email address) ____

Appendix C. **The Information sheet**

INFORMATION SHEET FOR PARTICIPANTS INVOLVED IN THE FOLLOWING STUDY.

Bilingualism and executive functions.

Dear Participant,

My name is XXXXXXXXX, and I am currently studying for an Honours degree in Psychology at the University of Adelaide. As part of my studies, I am conducting my thesis research on bilingualism and executive functions. Previous researches on bilingualism were looking mostly at bilingual children or on people who were bilingual from childhood. In my study I aim to focus on bilingual adults, who had been learned and used a second language later in life, beyond 18 years old.

PURPOSE OF THE STUDY:

You are being asked to participate in a University of Adelaide School of Psychology research study about bilingualism and its impacts on executive functions.

The influence of bilingualism on cognitive functioning is currently a topic of intense scientific debate. The strongest evidence for a cognitive benefit of bilingualism has been demonstrated in executive functions. The measures of executive functions, such as inhibitory, switching and working memory in bilingual adults will enable psychologists to address questions whether the learning second language has influence on executive functioning.

YOUR INVOLVEMENT IN THE STUDY:

Your participation in this study is voluntary. Participation will involve two tasks. Firstly, providing brief demographic information about you, educational background and language background, also a vocabulary test (for bilingual participants). Secondly, completing a series of tests on a computer (Stroop Task, Simon Task, Wisconsin Card Sorting Test, Trail Making Test and Tower of London Task).

In Stroop Task you will be given colour words written in colour and asked to indicate the colour of the word (not its meaning) by key press as fast as they can without making too many error.

Simon Task - Each Trail begins with a fixation cross in the center of the screen that remains visible for 800 ms and is followed by a 250 ms blank interval. At the end of this interval a red or blue square appears on either the left or the right side of the screen and remains on the screen for 1000 ms., If there is no response. You will be instructed to press the left shift key when you see a blue square and the right Shift Key when you see a red Square. Response timing begins with the onset of the stimulus, and the response terminates the stimulus. There is a 500 ms blank interval before the onset of the next trial.

In Wisconsin Card Sorting Test you are asked to sort cards into four different "categories". No instructions are given in regards to the categories rules. The four different categories are - one red triangle - two green stars - three yellow crosses - four blue circles. The cards to sort into these piles have similar design and vary in colour, shape and number.

In Trail Making Test - you are asked to move the mouse in specific, predetermined sequences from nodes to nodes.

In Tower of London Task you will need to figure out how to move and arrange three colourful discs on three provided pegs in such a way to achieve a specific solution pattern.

LOCATION OF THE STUDY:

The location of the study is within the School of Psychology, Hughes Building University of Adelaide, North Terrace. Hughes building, Room 230, this a research laboratory within the School of Psychology and is routinely used for cognitive testing.

The study should take no more than one hour to complete.

RISKS ASSOCIATED WITH THE STUDY:

There are no known risks associated with this stud. If you are feeling distressed at any point during the study, you are free to stop your involvement in the study.

WITHDRAWL: You may withdraw from being a participant in the study at any time that you wish to do so.

CONFIDENTIALITY OF DATA COLLECTED:

Your results will be coded by the computer and remain entirely confidential. The only information collected besides test scores is the sex and age. The information about you that will be collected for this research will be kept confidential between you and the School of Psychology (Faculty of Health and Medical Sciences, The University of Adelaide). The information will not be released to any third party. All information collected will be de-identified for data analysis.

CONTACT INFORMATION:

If you have any concerns or require clarification you may contact the university staff listed below.

name	**School**	**Role**	**Contact Details**
Ms XXXXXXXX	School of Psychology, University of Adelaide	Honours Student	Phone: [redacted]
Prof. Nick Burns	School of Psychology, University of Adelaide	Supervisor	[redacted] [redacted]
Prof Paul Delfabbro	Convener, School of Psychology, University of Adelaide	Human Ethics Subcommittee	[redacted] [redacted]

Appendix D. The Ethics Form

THE UNIVERSITY
OF ADELAIDE
AUSTRALIA

School of Psychology
University of Adelaide
North Terrace, Adelaide SA 5005
Ph. 61 8 8313 5693
Fax 61 8 8313 3770

School of Psychology: Human Research Ethics Subcommittee
Approval Sheet

Dear ......NICK......

The members of the subcommittee have considered your application:

Code Number: ......[redacted]

Title:

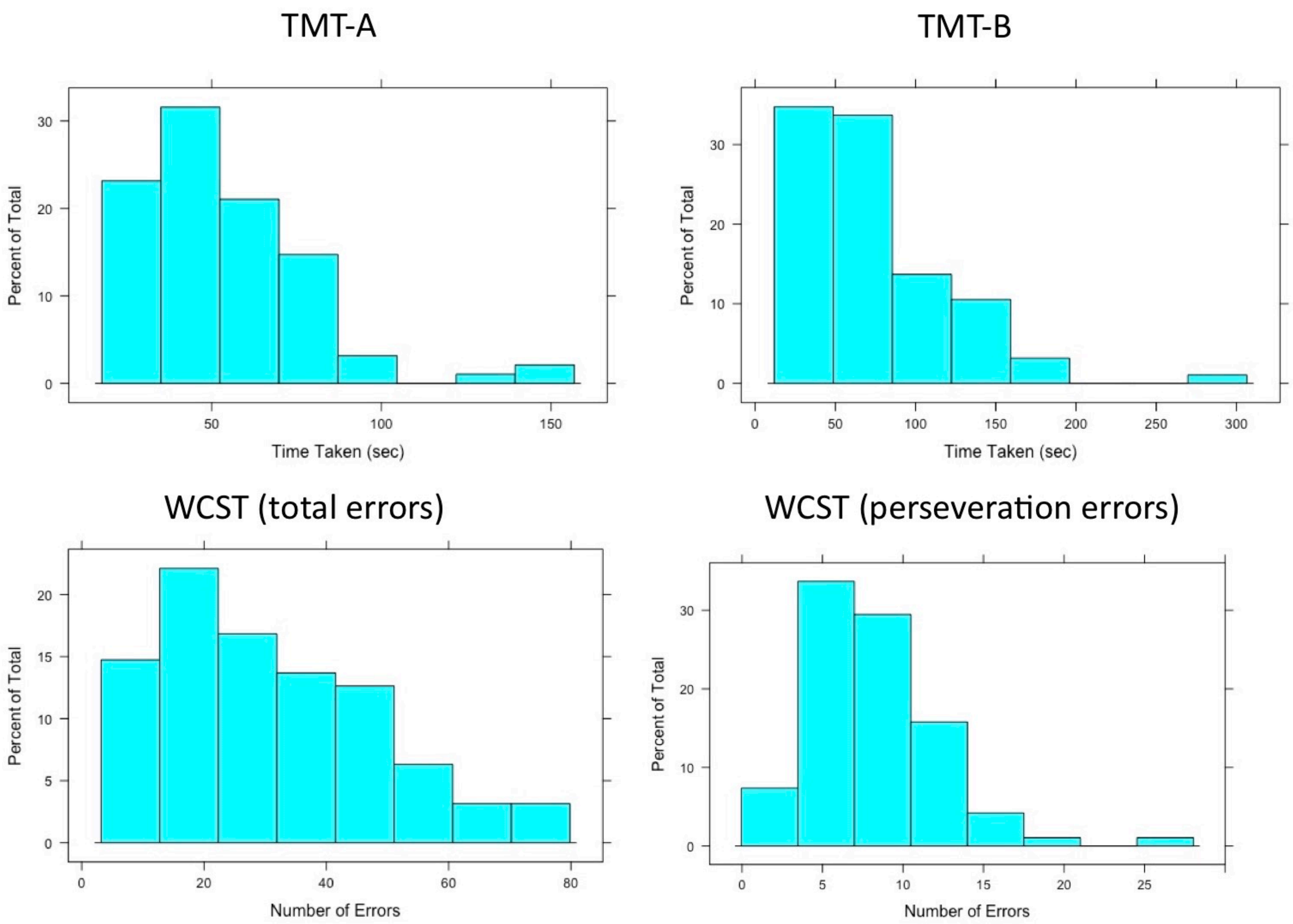
......BILINGUALISM & EXECUTIVE......
......FUNCTION......
....

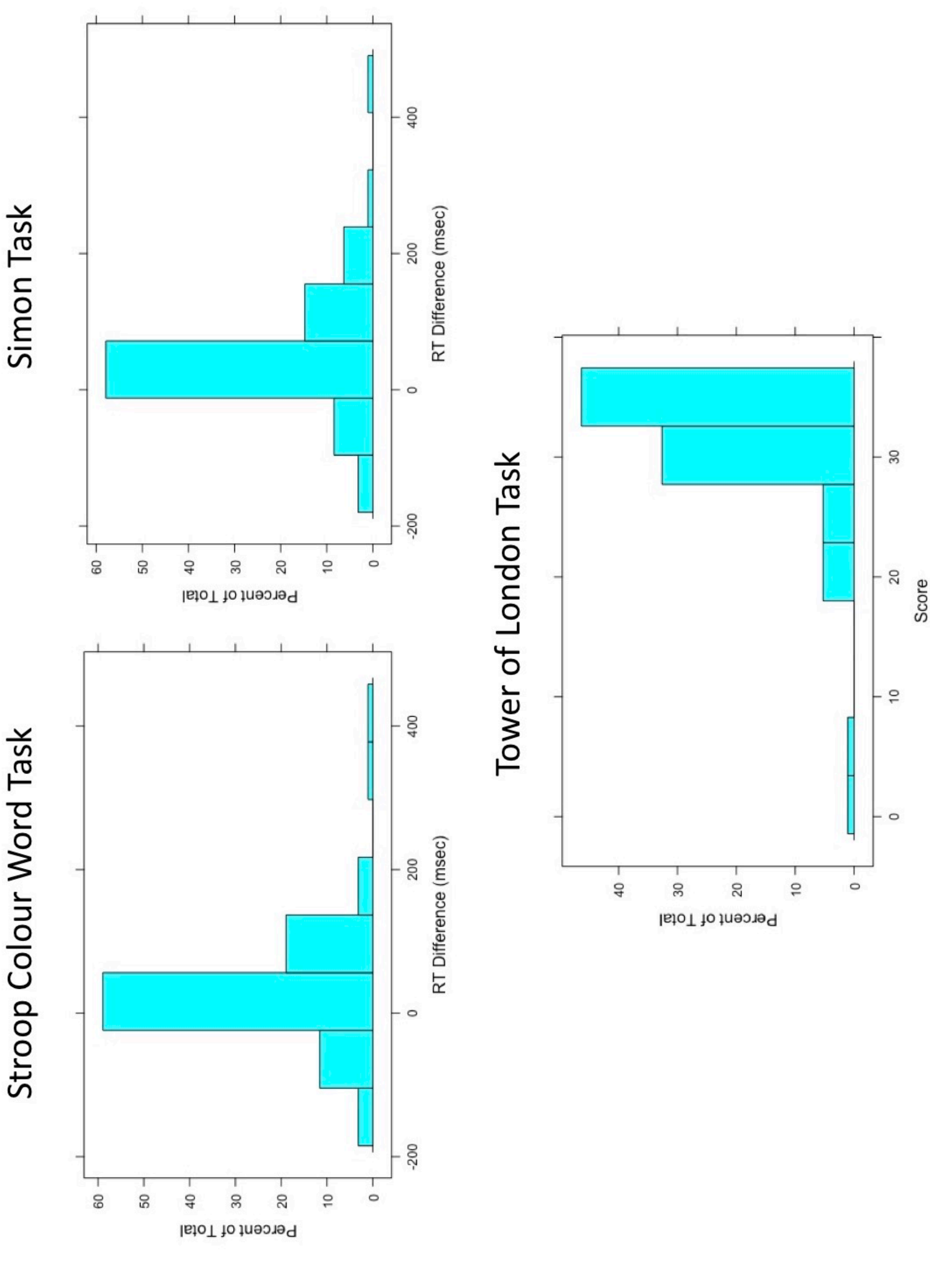
With (Student name, if applicable) [redacted]

I am writing to confirm that approval has been granted for this project to proceed. Approval is granted to 12 months from the date specified below.

[redacted]

Appendix E. The histograms of the data





Stroop Colour Word Task
Percent of Total
RT Difference (msec)
Simon Task
Percent of Total
RT Difference (msec)
Tower of London Task
Percent of Total
Score