

Is More Better?

The Effects of Multilingualism on Working Memory

MA Thesis

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Abstract

In the field of psycholinguistics cognitive benefits of bilingualism is a subject undergoing intense research. It was found that bilinguals outperform their monolingual peers on different tasks that involve various cognitive abilities, such as executive control, memory, metalinguistic awareness, etc. The following research run in parallel with a recent investigation in which an advantage was found for bilingual over monolingual adults in working memory (WM) performance. However, we took a step further and looked at bilingual and multilingual adults with different degrees of the third language (L3) knowledge.

38 native Dutch speakers aged 20 – 30 years participated in the current study. All of them were highly proficient in their second language (L2) and had varying degree of knowledge of L3. Our study aimed to investigate whether there is a positive relationship between L3 proficiency and use and the WM performance. Two specific working memory tasks were used: visuospatial WM was assessed with Corsi Block tapping task and verbal WM was assessed with Digit Span task. Participants' L2 and L3 proficiency and use was assessed by means of questionnaire. In addition, participants' socioeconomic status and fluid intelligence were measured as background variables that could influence WM performance. We predicted that L3 proficiency and use scores will be positively correlated with visuospatial WM outcomes but not auditory WM outcomes.

Hierarchical multiple regression analysis was used to answer the research question. Contrary to the expectations, statistical analysis revealed that there was no relationship between L3 proficiency/use and visuospatial WM performance. No relationship between L2 proficiency/use and visuospatial WM was found either, this goes against previous research that found that bilingualism has positive effect on visuospatial WM. In line with our predictions, there was no relationship between L3 proficiency/use and auditory WM. However, no strong conclusions can be drawn based on the results of statistical analysis with auditory WM as dependent variable because the assumption of normality was violated. More research is needed with larger sample and more sensitive measures of language proficiency.

1. Introduction

The majority of the modern world population is considered to be multilingual (Tucker, 1999), this implies that most people are able to speak at least two languages. In the situation of a rapid globalization such languages as English and Spanish are becoming lingua franca and knowing more than one language often predicts the success in the career of an individual, especially in the domains of business and higher education (Doiz, Lasagabaster & Sierra, 2013). This situation is encouraging more and more people to learn foreign languages, leading to unavoidable linguistic, cultural (Doiz, Lasagabaster & Sierra, 2013; Cleveland Laroche & Papadopoulos, 2015) and cognitive (Bialystok, 2011a) consequences. The extent of these consequences is the topic of debates for the researchers in many different fields. The current study focuses on the cognitive advantages of multilingualism¹ in one specific domain – working memory.

1.1 Cognitive benefits of bilingualism

In linguistics, the view on the bilingualism and its cognitive effects changed drastically over the period of the last century. Ranging from the perspective that raising children bilingual causes a delay in the mental development of a child and is a disability² (Saer, 1923; Arsenian, 1945; Darcy, 1946) to the more recent studies, which have found an extensive evidence for the cognitive advantages of bilingualism (Bialystok, 2011a). These advantages include enhanced executive control, metalinguistic awareness, memory and working memory (Adesope, Lavin, Thompson & Ungerleider, 2010).

The larger part of the studies investigating cognitive effects of bilingualism explored the area of executive control. In the review by Bialystok (2011a) three studies are presented that show the differences in performance between monolinguals and bilinguals on the tasks that involve additional cognitive effort and attention control.

The first study is by Bialystok (2010) and it tested monolingual and bilingual 6-year-olds on the global-local task. In this task participants are presented with stimuli (global) that are created out of smaller letters or shapes (local) and they need to pay attention to either global or local component of the stimuli (Navon, 1977). Depending on the match or mismatch between the global stimuli and the local one the trials can be:

- Congruent – the global is concordant with the local, e.g. letter L that consists of smaller letters L;
- Incongruent – the global is inconsistent with the local, e.g. letter L consists of smaller letters X.

Incongruent trials are considered to be much more demanding as they require additional attention control in order to resolve the discrepancy between the global and local features and react to only one of those.

Participants were presented with two different types of trials: simple trials, where stimuli were either congruent or incongruent and mixed block trials, where participants saw both congruent and

¹ It is important to note that here and further in this study the terms ‘multilingualism’ and ‘multilingual’ are going to be used to describe the knowledge of three or more languages, as opposite to ‘bilingualism’ and ‘bilingual’ – knowledge of two languages. Those two cases are going to be handled as a separate matter.

² Laurie in his ‘Lectures on language and linguistic method in the school’ in 1889 claims that: “If it were possible for a child or boy to live in two languages at once equally well, so much the worse for him. His intellectual and spiritual growth would not thereby be doubled, but halved” (Laurie, 1889: p. 18).

incongruent stimuli. The results of this study show that when children were presented with simple control conditions of either congruent or incongruent trials there was no differences in performance between monolinguals and bilinguals. However, in a mixed block of trials, when participants were presented with both congruent and incongruent stimuli, bilinguals outperformed monolinguals, showing the bilingual advantage when such components of executive control as monitoring and shifting are required (Bialystok, 2010: p. 14).

The second study compared the performance of 8-year-old monolinguals and bilinguals on classification tasks (Bialystok, 2011b). In the first task participants saw a picture of either an animal or a musical instrument and had to judge whether the picture belongs to the 'animal' or 'musical instrument' category by pressing the corresponding key. In the second task children were presented with sounds of either animal or musical instrument and they had to make a judgment regarding to which group the presented sound belongs by saying it out loud to the microphone. Next, participants had to perform a dual task, where first and second task were combined. Children were presented with a picture and the sound at the same time and they had to give two responses: to the picture by pressing the key and to the sound by saying the category to the microphone. In the first two tasks monolinguals and bilinguals performed similarly, but in the dual task, where additional attention control was required (Bialystok, 2011b), bilingual children performed significantly better than their monolingual counterparts.

The third study reviewed by Bialystok (2011a) compared younger (20 years) and older (68 years), monolingual and bilingual adults on different cognitive tasks, including the Simon arrows task, the Stroop task and the Sustained Attention to Response Task (SART) (Bialystok, Craik & Luk, 2008). All three tasks aim to test executive control as they include conflict resolution. The Simon arrows task had three conditions: in the first condition participants saw an arrow on the screen pointing to the left or to the right and they had to respond by pressing the respective key (left or right); in the second, reversed condition same stimuli were used, but this time participants had to press the opposite direction key; in the third, conflict condition the arrow appeared randomly on the right or left side of the screen and participants had to make a judgement on where the arrow is pointing, ignoring the position of the arrow on the screen. The position and the direction of the arrow were the same in congruent trials and different in incongruent trials. In the Stroop task participants see a name of the colour on the screen, the colour of the font is matched with the name of the colour in congruent trials (e.g. name of the colour 'green' is actually presented in the green colour) and mismatched in incongruent trials. Participants need to name the colour of the font as fast as they can. When performing SART participants see the numbers from 1 to 9 appearing randomly on the screen, as soon as they see a number they have to react to it by pressing the response key, unless the number 3 appears, in this case participants were asked not to press the key and wait for the next number to appear. Overall, the analysis of the reaction times (RT) show the bilingual advantage when comparing results for the simple control conditions and experimental conditions of the Simon and Stroop tasks, but no bilingual advantage emerged when performing SART. In Simon and Stroop tasks bilinguals show smaller differences in RT between control and experimental conditions resulting in smaller Simon effect for older bilinguals and a smaller Stroop effect for the bilinguals of both age groups (Bialystok, Craik & Luk, 2008: p. 869).

Moreover, Bialystok, Craik & Luk (2008), based on the results of their study, explain the underlying cognitive processes involved in language use in bilinguals. Previous studies suggest that in bilinguals both languages are activated at the same time (e.g. Green, 1998; Dijkstra, Grainger & Van Heuven, 1999; Kroll, 2008), in order to resolve the conflict between two languages and use only the intended language, bilinguals have to employ executive control. Interference suppression and response inhibition are two fundamental components of cognitive control (Bunge, Dudukovic, Thomason,

Vaidya & Gabrieli, 2002: p. 301). Interference suppression is the ability to ignore the salient element of the environment and attend to the non-salient, conflicting element (e.g. the conflict condition of the Simon arrows task – participant needs to attend to the direction of the arrow while ignoring its location). Response inhibition is the ability to inhibit the prevalent response in favour of non-dominant response (e.g. the reversed condition of the Simon arrows task – participant needs to attend to the direction of the arrow but responds by pressing the key of opposite direction) (Esposito, Baker-Ward & Mueller, 2013). During daily language use bilinguals need to attend to one of their languages while ignoring another one by suppressing it, leading to cognitive enhancement of interference suppression ability. Indeed, on the trials that require interference suppression, such as incongruent trials of Simon arrows and Stroop tasks bilinguals performed significantly better than monolinguals. As to response inhibition, it is still not clear if and to what extent it is involved in bilingual daily language use. The reversed Simon arrows task condition and SART require response inhibition and in those tasks both language groups performed similarly (Bialystok, Craik & Luk, 2008: p. 869).

Some studies demonstrate that bilingual advantage can be found even in early childhood. A study by Poulin-Dubois, Blaye, Coutya & Bialystok (2011) found that bilingual children as young as a 24-month-olds show an enhanced executive control compared to their monolingual peers when performing the Stroop task, suggesting that the advantages of bilingualism emerge at this early age. Brito, Grenell & Barr (2014) examined memory in monolingual, bilingual and trilingual 24-month-olds and found that bilinguals (but not trilinguals) outperformed monolinguals on memory generalisation task. No language group differences emerged when performing working memory and cued recall tasks.

A number of studies suggest that bilingualism has a positive effect on the aging brain, with some studies showing that the symptoms of dementia are delayed in aging bilinguals as compared to monolinguals (Bialystok, Craik & Freedman, 2007; Craik, Bialystok & Freedman, 2010; Alladi, Bak, Duggirala, Surampudi, Shailaja, Shukla, Chaudhuri & Kaul, 2013; Woumans, Santens, Sieben, Versijpt, Stevens & Duyck, 2015) and this bilingual advantage is present even for the participants who acquired a second language later in adulthood (Bak, Allerhand & Deary, 2014). The results of Bak et al. (2014) also show that knowing three languages has a bigger effect on cognitive functions than knowing two, this has been suggested earlier by Chertkow, Whitehead, Phillips, Wolfson, Atherton & Bergman (2010) who, based on their results, conclude that multilingualism is a better protector against the age-related memory loss than bilingualism.

Effects of bilingualism on long-term memory was not examined as thoroughly as effects on executive control, though it is clear that language and memory processes are interconnected. Long-term memory contains the knowledge obtained over a long period of time. It includes explicit memory (that contains facts and events) and implicit memory (responsible for skills, routines and associations) (Altarriba & Isurin, 2013: p. 9). It is believed that explicit memory (also called declarative memory) contains the mental lexicon and implicit (procedural) memory contains aspects of the grammar (Ullman, 2004: 233). Kormi-Nouri, Moniri & Nilsson (2003) studied episodic and semantic memory (both are part of explicit memory) in monolingual and bilingual children. To assess episodic memory subject-performed and verbal tasks were used. In those tasks participants were presented with short phrases that were encoded either verbally (participants had to listen and repeat phrase) or by action (participants had to listen and perform an action based on the phrase, e.g. "give me the spoon"). Semantic memory was assessed by the means of word fluency tests. The results show bilingual advantage in episodic memory encoded by action and semantic memory but not in verbally encoded episodic memory. Authors conclude that because in bilinguals two languages are integrated

in memory, they are more flexible in retrieving the relevant information (Kormi-Nouri, Moniri & Nilsson, 2003: p. 51).

The only study that was found which compares cognitive functioning in multilinguals with different number of known languages (bilinguals, trilinguals, quadrilinguals, etc.) is a research done by Matser (2016). In her master's thesis she compared individuals with varying degree of multilingualism on the ability to recognise patterns. The statistical learning task was used and different factors besides multilingualism were examined, such as age, gender, age of acquisition of foreign language, etc. On average, participants who knew three languages got higher scores on pattern recognition task than those who knew more or less languages. (Matser, 2016: p. 36). However, contrary to the expectations, this difference was not significant, indicating that there was no relationship between number of languages and the ability to identify patterns.

The evidence for bilingual advantage in cognitive functioning has been found across all ages, from infancy and to late adulthood. Nonetheless, this picture of strong bilingual advantage was criticized by de Bruin, Treccani, & Della Sala (2015) whose results show that there might be a publication bias that skews the overall findings, when only papers that prove bilingual advantage are being published, leaving out studies that find null or negative results. As a response to those concerns Bialystok, Kroll, Green, MacWhinney & Craik (2015) assert that "the crucial question is not the presence or absence of publication bias, but whether or not convincing evidence exists to support claims that bilingualism has systematic and enduring consequences for cognitive and brain function" (Bialystok et al., 2015: p. 2).

1.2 Working memory

Working memory (WM) is a theoretical temporary storage system, necessary for a variety of complex cognitive activities. In 1968 Atkinson and Shiffrin suggested a multi-store model of memory that includes sensory register, short-term store and long-term store (Atkinson & Shiffrin, 1968). It also explains how the memory processes work. In this model, the short-term store (also called WM) is the system that gets the information from the sensory register and stores it for 15-30 seconds before it is rehearsed, otherwise the information decays and disappears. From the short-term store the information is transferred to the long-term store. The Atkinson-Shiffrin memory model was very influential and procreated a lot of research (McLeod, 2012). However, the model was found to be over simplistic and it was criticized for that. WM in a multi-store model was treated like a simple, unitary system, without any subsystems.

Baddeley & Hitch (1974) proposed a WM model that is still referred to, with the central executive as its core and two dependent subsystems, the phonological loop and visuospatial sketchpad. Later, a third subsystem called the episodic buffer was added (Baddeley, 2000). The description of the current version is in Baddeley (2003) (Fig. 1), where he concludes that if this model is accurate, it should have important implications for language processing. Those implications, as well as the functions of WM subsystems are described further in the text. Specifically, we focus on the possible role of different WM subsystems in the language learning process.

It is believed that the central executive is responsible for attention control. Daneman & Carpenter (1980) tested participants using the reading span task, in this task participants had to read sets of sentences and after reading a set they had to recall the last word of each sentence in a set. The reading span was measured as the number of sentences the participant could read while still being able to correctly recall the last word of each sentence. The study found a correlation between the reading

span and the reading comprehension measures, implying that the differences in the WM span of the individuals are most likely due to the underlying executive processes. Baddeley (2003) mentions that WM capacity influences the capability of an individual's reading comprehension.

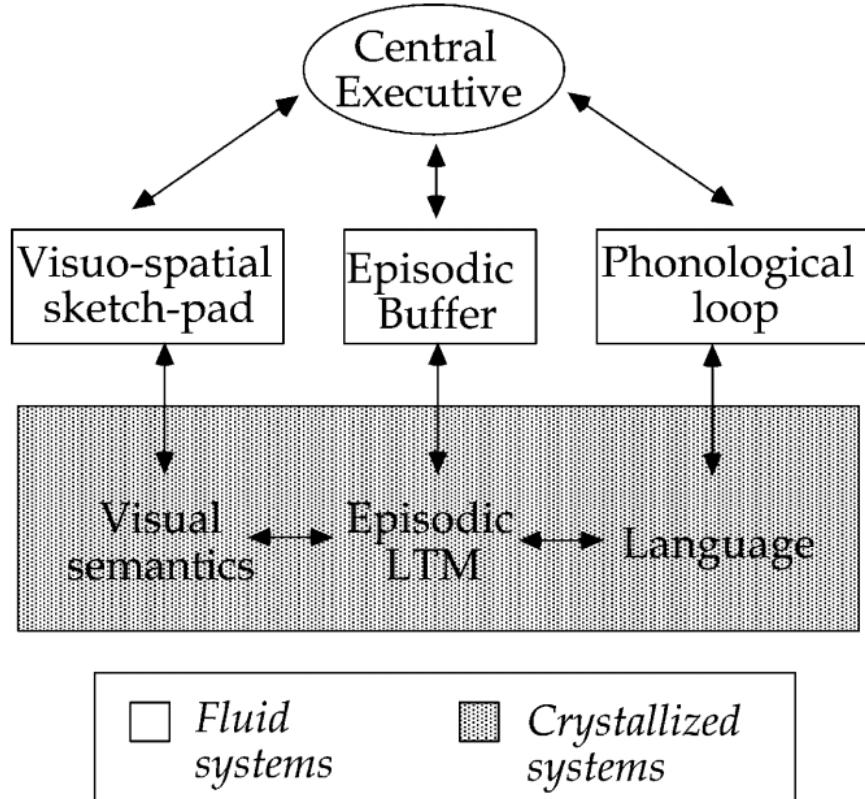


Fig. 1. The current working memory model presented in Baddeley (2003). Fluid systems are responsible for the episodic, temporary memory and crystallized systems store long-term information.

The phonological loop stores verbal/acoustic information. It appears that this subsystem has more influence on the language processing than any other component of the WM. The phonological loop consists of two components: the subvocal rehearsal system that keeps the pieces of auditory information until the next piece of information is presented and the storage. A study conducted on a patient with phonological short-term memory deficit found that although the patient had no problems remembering the random word pairs in her native language (Italian), she could not learn new word pairs that consist of words in the language she did not know (Russian) (Baddeley, Papagno, & Vallar, 1988). Those results show that phonological loop is a necessary tool in the acquisition of the new language. As to the native language acquisition – the phonological storage capacity was found to be an important component when learning the mother tongue. A study by Gathercole & Baddeley (1989) tested children at the ages of 4 and 5 and found that the performance on a nonword repetition task at the age of 4 predicted the vocabulary score at the age of 5.

The second WM model subsystem, the visuospatial sketchpad, is responsible for temporal storage and manipulation of visual and spatial information, it combines visual and spatial memories together into a complex storage unit. At first sight, the visuospatial sketchpad seems to be not as significant

for language processing as the phonological loop, yet, this WM subsystem is supposedly involved in such daily language activity such as reading (Baddeley, 2003).

Finally, the episodic buffer was proposed when it was found that patients with long-term memory impairment could nevertheless recall large amounts of information, such as prose passage or cards played in the bridge game, which is way beyond the capacity of the WM storage in the old model. The episodic buffer is dependent on the central executive and is responsible for storing small amounts of information. It combines different modalities of the memory into chunks – or ‘episodes’ – and it provides the connection between WM and the long-term memory.

It is worth to mention that Baddeley & Hitch’s WM model is not the only theoretical model that exists nowadays. For example, Cowan (1998) and Ericsson & Kintsch (1995) models of WM were proposed as alternatives. However, the Baddeley & Hitch WM model is the most relevant to this study as it accounts for a WM involvement in a wide range of linguistic activities, such as reading, comprehension, etc. Among researchers in linguistics who consider this model accurate, it is believed that working memory is significantly involved in the ability to learn a second language (Linck, Osthus, Koeth & Bunting, 2014). Ardila (2003) posits that in bilinguals, brain activation patterns during WM tasks are more complex when using their L2, which is considered a more demanding task.

1.3 Bilingualism and working memory

A review by Adesope, Lavin, Thompson & Ungerleider (2010) concludes that even though there is a small number of studies on bilingual advantages in working memory category, bilingualism is generally associated with greater working memory performance. A major part of research in this area was done with child participants: a study done by Morales, Calvo & Bialystok (2013) compares working memory performance in young bilinguals and monolinguals on tasks requiring different levels of WM. Their results favoured the hypothesis that bilinguals have larger WM capacity than monolinguals, as bilinguals performed better than monolinguals in all tasks.

Blom, Küntay, Messer, Verhagen & Leseman (2014) examined WM in monolingual Dutch children and Turkish-Dutch bilingual children. They found that bilingual 6-year-olds performed better on some of the visuospatial and verbal WM tasks when the analysis was statistically controlled for Dutch vocabulary and socioeconomic status. Those results support the idea of bilingual cognitive advantage that emerge even in situations unfavourable to the development of WM.

Another paper that investigated cognitive development in ethnic minorities is by Goriot, Denessen, Bakker & Droop (2015) who compared Dutch monolingual, German-Dutch and Turkish-Dutch bilingual children and found that the teachers’ appreciation of the home language of the child affects the bilingual advantage in executive functioning. Specifically, home language tolerance (the teachers’ appreciation of participants’ home language use at school) was associated with both verbal and nonverbal WM. The results show that German-Dutch bilinguals received more appreciation of their home language use at school than Turkish-Dutch bilinguals, this appreciation was also positively correlated with working memory scores. In line with previous findings the study also found bilingual advantage on nonverbal WM and switching tasks (Goriot, Denessen, Bakker & Droop, 2015: p. 10)

However, Engel de Abreu (2011) investigated working memory performance in multilingual and monolingual children and found that there was no language group effect and therefore, this study suggests that the multilingualism does not affect working memory abilities. Though, it is important to note that in this study the tests that were used in order to assess WM were only verbal (no

visuospatial WM tasks were used) and bilinguals often score lower than monolinguals on the verbal tasks.

Moving further we find some studies that focus on adult bilingual WM. A paper by Ransdell, Barbier & Niit (2006) compared monolingual and bilingual/multilingual university students in three different countries with different language backgrounds, the findings of this paper show bilingual and multilingual students have better WM and metalinguistic awareness of their language skills in reading than monolingual students. Another important study concerning bilingual adult WM performance is done by Luo, Craik, Moreno & Bialystok (2013), they have tested younger and older adults using spatial and verbal working memory tasks. The results show that monolingual participants performed better on the verbal span measures, but the bilinguals had an advantage over monolinguals on the spatial tests. Based on the previous research the following conclusions could be drawn: there is some evidence for a difference in WM performance between mono- and multilinguals. However, more studies are needed in order to draw firm conclusions regarding multilingual advantage in this particular area.

These findings, along with the lack of overall research on the topic, encouraged us to take a further look into it; to our current knowledge, no other studies have compared bilingual and multilingual adults working memory performance with two types of WM task. Thus, we follow a path similar to Luo, Craik, Moreno & Bialystok (2013) in that we examine working memory in bilingual and multilingual adults, and taking into account their main findings, we aim to answer the following research question: *are there any differences between bilingual and multilingual adults regarding their WM performance?*

In line with Luo, Craik, Moreno & Bialystok's (2013) observations, we expect that multilingualism positively affects working memory performance. Thus, the hypothesis to be tested is: *third language proficiency and use will be positively correlated with visuospatial WM performance but not with verbal WM performance.*

In the present study, in our experiment, we use both verbal and visuospatial tasks. Yet, we expect to find no multilingual advantage over bilinguals on verbal tasks, since most previous studies failed to find bilinguals advantage over monolinguals when using tasks akin to these (e.g. Engel de Abreu, 2011). We decided, thus, to follow a similar line of thought. Because on verbal WM tests bilinguals usually show no difference or disadvantage when compared to monolinguals we expect to find similar results when comparing bilinguals and multilinguals. At the same time, we predict that multilinguals will outperform bilinguals on visuospatial WM tasks, showing that multilingual advantage extends beyond bilingualism.

If we find evidence in support of the hypothesis, it might fill another research gap regarding WM in bilingual and multilingual adults. On the other hand, if results are not significant in our study, it means we should take a closer look at those that have not reached significant results either (e.g. Engel de Abreu, 2011), and perhaps consider other factors that may have contributed to said findings.

2. Method

2.1 Participants

For this study a sample of 38 Dutch native speakers was collected, all participants had English language as their second language (L2) and most of participants had a knowledge of the third language (L3) to some extent. All participants are healthy adults and were recruited through Radboud Research Participation System. Their age ranges from 20 to 30 years ($M = 22.84$). The age was not controlled for as we do not expect older participants to have a working memory loss at this early age.

Participants had to be right-handed and have normal or corrected-to-normal vision. In addition, the exclusion criteria for participation in this study was any type of colour blindness or dyslexia (in Radboud Research Participation System participants have to fill in the “screening” form during the initial registration, this allows researchers to set particular exclusion criteria for participants, preventing individuals who are not suitable for the study from participation). The colour blind individual might have struggles performing Corsi Block-tapping task as it requires attending to the different colours of the blocks. Dyslexia was found to impair performance on the tasks that involve phonological loop (a subsystem of the WM) functioning (Jeffries & Everatt, 2004; Schuchardt, Maehler & Hasselhorn, 2008).

As the assessment of L2 and L3 proficiency participants filled in self-rating form as well as a brief questionnaire on the amount and variety of language input they receive outside and within the academic environment.

As additional control measures, participants were asked about their and parental socioeconomic status and had to perform a short intelligence test, since it has been found that those variables could influence WM performance (Hackman, Betancourt, Gallop, Romer, Brodsky, Hurt & Farah, 2014).

Participants were rewarded with 10 euros in VVV coupons for their participation.

2.2 Measures

2.2.1 Language proficiency and daily language use

In order to assess participant’s language experience a language background questionnaire was used (Appendix A). Participants had to answer questions about their childhood language input as well as their first exposure to the second language. Daily language use and language proficiency were determined using self-assessment. Participants were asked to list all the languages they know, even if they do not consider themselves as proficient users, and rate themselves on the scale from 1 (very bad) to 7 (fluent) on four different parameters: reading, writing, listening and speaking. In order to avoid any misunderstandings, the questionnaire was in Dutch, which is the native language for the participants. Although self-assessment is not the most reliable way to measure someone’s language proficiency, it was chosen as the best option within the limited time and resources of this study.

2.2.2 Socioeconomic status

The second background measure is the socioeconomic status (SES). Cognitive abilities in general and WM in particular are positively correlated with SES (Noble, McCandliss & Farah, 2007). The level of parental education is generally used as an estimation of SES of the family (Blom, Küntay, Messer, Verhagen & Leseman, 2014) and it was found that lower parental education is associated with a worse performance on WM tests (Hackman, Betancourt, Gallop, Romer, Brodsky, Hurt & Farah, 2014). In our study participants were asked about the level of education of their parents as well as their own level of education. We decided to include the level of education of participants themselves because even though young adults are still largely dependent on their parents socioeconomically, in the Netherlands they tend to live separately from their families and form their own SES. If there are any differences comparing current SES of participants with the SES of their parents we should take them into account because the effects of SES on cognitive abilities continues into the adulthood (Noble, McCandliss & Farah, 2007). Blom, Küntay, Messer, Verhagen & Leseman (2014) measured participants' SES by taking the mean of the highest attained educational level of both parents rated on a 6-point scale. Similarly to this, the measure of SES in the current study is the mean of highest attained education of both parents and a participant on the 8-point scale (Basisschool – 1; VMBO – 2; HAVO – 3; VWO – 4; MBO – 5; HBO – 6; Universiteit – 7; Doctor – 8).

2.2.3 Fluid intelligence task: Raven's Standard Progressive Matrices test

Fluid intelligence is the ability for reasoning and problem-solving that does not rely on previously acquired knowledge (Jaeggi, Buschkuhl, Jonides & Perrig, 2008). Working memory performance seems to be closely related to the fluid intelligence of an individual (Salthouse & Pink, 2008; Unsworth, Fukuda, Awh & Vogel, 2014), therefore, it is important to control for this variable when analysing the results of working memory tests.

There are various ways to measure participants' fluid intelligence. The Raven's Standard Progressive Matrices test (Raven, 1974) is commonly used to measure individuals' general cognitive ability (Arthur & Day, 1994) and considered to be a good estimation of non-verbal fluid intelligence (Bilker, Hansen, Brensinger, Richard, Gur & Gur, 2012). The Raven's Standard Progressive Matrices (RSPM) test consists of 60 items. An item is a graphical black and white geometrical picture where one piece of the design is missing, below 6 or 8 options are presented that could fill in the gap but only one option fits the best in the bigger design. An example of the item from RSPM test is given in Fig. 2.

The major drawback of this test is the administration time, on average, it takes 40 – 60 minutes to perform the test (Raven, 1974). Several studies have attempted to develop a shorter version of the test that would have the score equivalent to the full RSPM test but have a substantially smaller administration time (Arthur & Day, 1994; Hamel & Schmittmann, 2006; Bilker, Hansen, Brensinger, Richard, Gur & Gur, 2012). For the current study the nine-item version of RSPM test developed by Bilker et al. (2012) was chosen. In their research two nine-item subsets (Form A and Form B) of the original RSPM were developed that have a high correlations with the full version of the test. We choose the Form A as its scores had bigger correlation with the scores on original RSPM test; it consists of the following items presented in full RSPM: 11, 24, 28, 36, 43, 48, 49, 53, and 55 (Bilker et al., 2012). Participants were given verbal instructions according the RSPM administration brochure (Raven, 1974) and were asked to choose an appropriate pattern that fills in the gap. In our study participants were additionally presented with an item number 1 (Fig. 2.) of the full RSPM test before they proceed to the short version of RSPM. They had to give the oral answer to this item to the experimenter and the answer was not taken into account when calculating the score of an individual.

This was done to make sure participants understand the objective of the test and to avoid any misinterpretation. There were no time limits for this test and participants could take as much time as they needed to perform it.

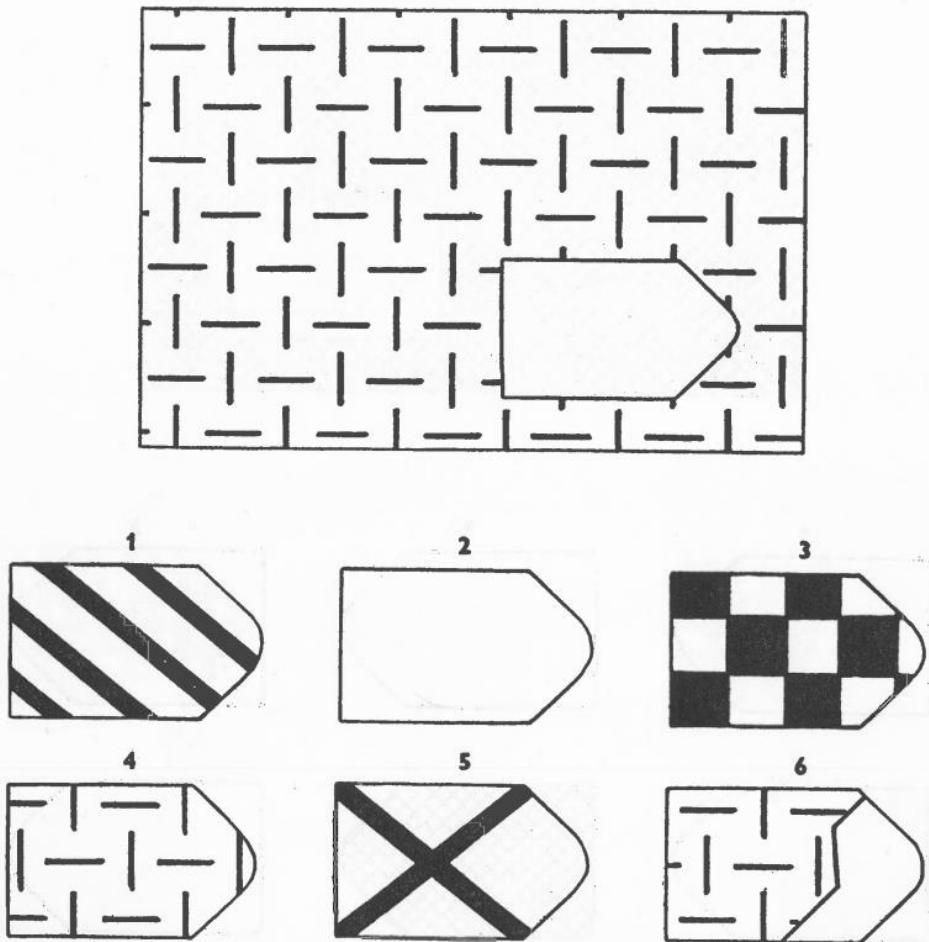


Fig.2. An example of the item in Raven's Standard Progressive Matrices (Raven, 1974).

Similar to the full version of RSPM each item (except for practice item number 1 in our study) had a value of 1 if participant gave a correct answer, therefore, participant could get a total score ranging from 0 to 9. This score was used as a measure of participants' fluid intelligence.

2.2.4 Visuo-spatial working memory tasks: forward/backward Corsi Block-tapping task

In order to assess participants' visuo-spatial working memory performance the computerized version of Corsi blocks task (Corsi, 1972) was employed; this test "captures the development of the ability to mentally manipulate visuospatial information" (Morales, Calvo & Bialystok, 2013: p. 8). This task is most commonly used to test non-verbal short-term memory (Della Sala, Gray, Baddeley, Allamano & Wilson, 1999). Nine blue same-size square blocks are randomly presented on a grey background on the computer monitor (Fig. 3). Participants are required to look at the blocks as they lit up (change colour from blue to yellow) in a particular order. The trial starts with a sequence of three blocks (two in the backward condition); once the sequence has been shown, the participant

needs to repeat the sequence by clicking on the respective squares with the left click of the mouse and press right click of the mouse when finished. If the answer is correct, the number of blocks that light up increases, in case of failure participant gets one more chance. After two failed attempts the task stops and the maximal number of the blocks correctly recalled is the measure of participants' visuo-spatial working memory span called Block Span.

In the 'forward' condition participants are asked to repeat the sequence of the blocks in the same way they were presented and in the 'backward' condition participants have to repeat the sequence reversed, starting from the block they saw last and finishing with the one they saw first.

The result of Corsi block task on average is 6.2 blocks ($SD=1.3$) for healthy participants (Kessels, Van Zandvoort, Postma, Kappelle & De Haan, 2000) in the 'forward' condition. However, Block span itself might not be a very sensitive measure as it is represented with only one final score of the participant. Total Score is a measure of visual working memory proposed by Kessels, Van Zandvoort, Postma, Kappelle & De Haan (2000), it is considered to be a more reliable measure than Block Span itself, as it takes into account the number of correctly produced sequences across the task. Total Score is a product of individuals' Block Span and the number of correct trials (Kessels, Van Zandvoort, Postma, Kappelle & De Haan, 2000). In our study we decided to follow similar path and calculate the score that would be more reliable than Block Span and Total Score proposed by Kessels, Van Zandvoort, Postma, Kappelle & De Haan (2000). In order to get more sensitive measures each participant had to perform 14 trials in each condition (forward/backward) and the Corsi Total Score was calculated as the sum of numbers of blocks in all correctly recalled trials. By taking into account performance across all 14 trials we hope to get the best representation of participant's visuo-spatial WM abilities.

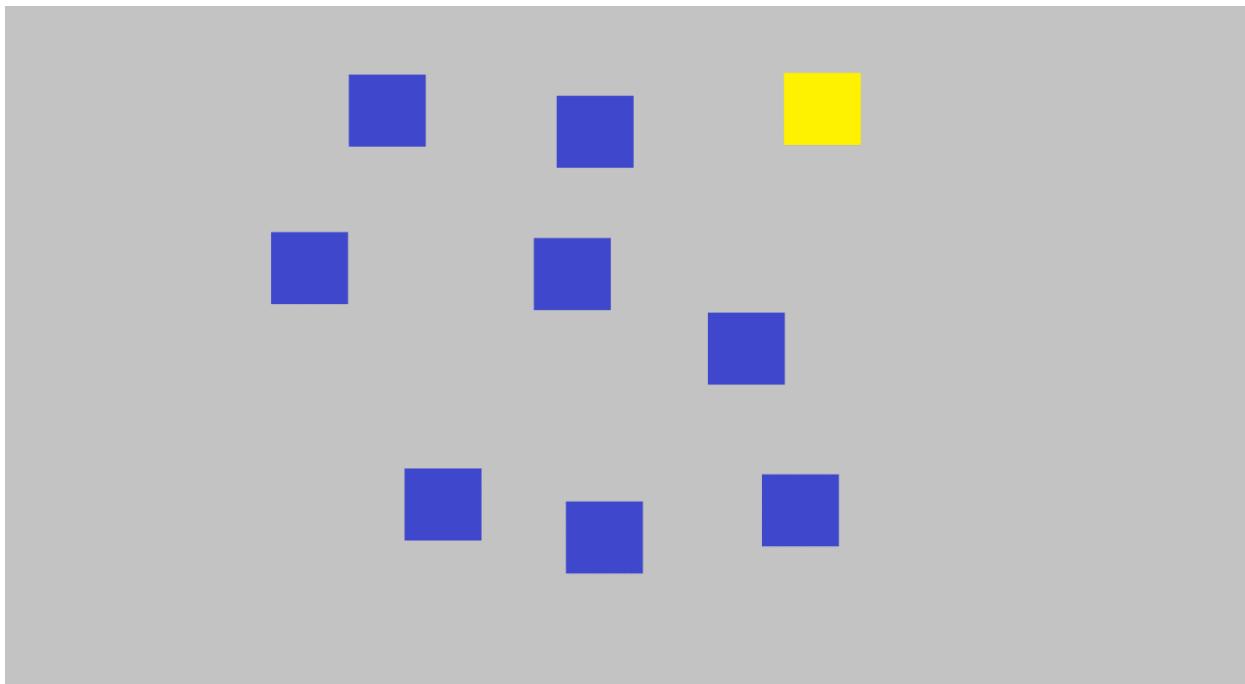


Fig.3. Example of the computerized version of Corsi blocks task. The yellow square represents the current block in the sequence.

2.2.5 Verbal working memory tasks: auditory forward/backward Digit Span task

Digit Span task is one of the oldest and most widely used verbal working memory tasks (Richardson, 2007). The computerised version of the Digit Span task was used as it is more reliable and precise assessment of the verbal WM than a traditional paper-and-pencil way of testing (Woods, Kishiyama, Yund, Herron, Edwards, Poliva, Hink & Reed, 2011). Participants hear the sequence of numbers through headphones, after that they have to repeat it in the right order by typing the respective numbers on the keyboard. The task starts with the sequence of three numbers and increases by one number after each trial if the participant successfully repeated the sequence. The task stops when participant makes two consecutive mistakes. In the ‘forward’ condition participants have to repeat the sequence in the same order they hear it and in the ‘backward’ condition participants have to reverse the order of the numbers.

Similarly to the Corsi Block-tapping task, a traditional measure for the Digit Span task is two-error maximal length, it is the maximal length of correctly recalled number sequence before two consecutive mistakes were made. However, Woods, Kishiyama, Yund, Herron, Edwards, Poliva, Hink & Reed (2011) criticise this measure because it can only show precision up to one digit and it ignores performance variability. Instead, they propose a new measure, Maximal length, which is the maximal length of correctly recalled sequences across 14 trials in which a 1:2 staircase method is used: “that is, a single correct response increased the length of the subsequent list by one digit, while two incorrect responses were needed to reduce the list length by one digit” (Woods et al., 2011: p. 103). We are going to use this method in a current study, but similarly to Corsi Block-tapping task the Digit Total Score will be calculated in order to get more reliable data.

2.3 Procedure

The testing took place in July 2016 in one of the laboratory rooms of Centre for Language Studies (CLS) at Radboud University. Participants were tested one by one on different times and days of the week (working days, 9 a.m. – 5 p.m.). They were seated in a soundproof booth during the entire experiment, they could open the booth at any moment in case of emergency or if they had any questions. On average, it took 45 – 60 minutes for each participant to be tested, all the experiments were self-paced and participants could take as much time as they needed to perform the tasks as accurately as possible. Regarding this they were given explicit instructions. All the oral instructions were given in English because high English proficiency was one of the main requirements for participation in this study³.

Every experimental session was conducted in the same way as the previous one to avoid any discrepancies that could lead to differences in the performance of participants. The order of the tasks and procedures was following:

1. The experimenter picked up the participant at the waiting area of the CLS laboratory, the participant’s ID number (provided by Radboud Research Participation System) was checked in order to make sure the right participant was picked up.
2. The participant received verbal instructions to stop the experiment at any point of time if they have any concerns or questions regarding of understanding of what they need to do. This was necessary to prevent any misunderstandings and avoid data loss.

³ Also due to experimenters’ poor Dutch language proficiency.

3. After that the participant was seated in a soundproof booth and was presented with the Information brochure and the Consent form that they had to sign.

4. Experiment started with WM tasks: Corsi Block-tapping task was presented first for the half of participants following by Digit Span task, for another half of participants first task was Digit Span following by Corsi Block-tapping task. Both tasks were performed on Dell Precision T3600 PC, visual stimuli were presented on the Ben Q XL 2420T 24" Full HD monitor. The software used for the WM tasks was Presentation® program developed by Neurobehavioral Systems Inc. WM tasks were taken from a package Cognitive Psychology Experiments III (Version 3) provided by Neurobehavioral Systems⁴.

Prior to performing the Corsi Block-tapping task participants received verbal instructions which were followed by written instructions in English presented on the computer monitor. The task required to use a computer mouse: left click to select the blocks, right click to proceed to the next trial. Three practice trials were presented before the experimental trials started (the performance on the practice trials was not taken into account when analysing the data). After completing 14 trials in forward condition, participants saw instructions for backward conditions. They were additionally verbally informed that in backward condition blocks had to be recalled backwards: starting from the block they saw last and finishing with the block they saw first. Next, they had to perform 14 trials in backward condition, finishing the Corsi Block-tapping task.

For the purpose of this study the Digit Span task available in Cognitive Psychology Experiments III (Version 3) package had to be modified due to the absence of the Dutch version of this task. It was necessary to provide participants with the task in their native language because the performance on the Digit Span task is highly dependent on the phonological loop and therefore on the verbal skills of an individual. The original English instructions were translated into Dutch by a native Dutch speaker and were verified and corrected by two other native speakers. New auditory stimuli in Dutch were recorded by the native speaker. To perform Digit Span task participants had to use numbers on the keyboard and 'Enter' key, the auditory stimuli were delivered through the headset. Similarly to the Corsi Block-tapping task, participants had verbal and written instructions before performing 14 forward trials, followed by verbal and written instructions and 14 trials in backward condition.

5. Upon finishing WM tests, participants were given a printed Language questionnaire in Dutch which they had to fill in using a pen.

6. The RSPM test was given to participants in a paper form, they received verbal instructions and were asked to give an answer to the first item of the test as the practice item to make sure they understand the objectives of the test. Just like WM tasks, participants were told that there are no time limits to prevent participants from responding haphazardly. They had to circle the correct option with a pen.

7. At the end of the session participants had to fill in the VVV coupon form for administration purposes.

All the data collected was anonymous and no participants can be identified.

⁴ Downloaded from https://www.neurobs.com/menu_presentation/menu_teaching/exp_pack?pack_id=8 ; link available on 21.09.2016.

3. Results

Two Hierarchical Multiple Regression analyses were performed in order to investigate possible relationships between L3 proficiency/use and visuospatial/auditory WM measures, while controlling for fluid intelligence, SES and L2 proficiency/use.

3.1 Visuospatial working memory

Following assumptions of the Multiple Regression analysis had to be checked in order for the results to be reliable:

- No outliers. Outliers are individual cases that are not predicted by the model, in some cases outliers can affect the model itself and therefore should be excluded. An analysis of standard residuals was carried out including Mahalanobis distance and Cook's distance, which showed that data contained no outliers (*Mahal. distance Max = 14.74; Cook's distance Max = .42*);
- No multicollinearity. Multicollinearity means that there is a strong correlation between two or more predictor variables, which implies that one variable might be predicted from the other. Tests that were performed to see if the assumption of collinearity was met indicate that in this analysis multicollinearity was not a concern (Fluid intelligence, *Tolerance = .78, VIF = 1.28*; SES, *Tolerance = .77, VIF = 1.31*; L2 proficiency, *Tolerance = .71, VIF = 1.41*; L2 use, *Tolerance = .66, VIF = 1.28*; L3 proficiency, *Tolerance = .64, VIF = 1.57*; L3 use, *Tolerance = .63, VIF = 1.58*);
- The linearity, homogeneity and normality. The linearity assumption means there should be a linear relationship between dependent and independent variables and homogeneity implies that our data should be homogeneous (meaning that the elements in our data are of the same kind). The scatterplot of standardised residuals (Appendix B, Fig. 1) showed that the data met the assumptions of homogeneity of variance and linearity. Normality assumption requires dependent variable to be normally distributed. The histogram of standardised residuals (Appendix B, Fig. 2) indicate that the data is approximately normally distributed, this is also shown by normal P-P plot of standardised residuals (Appendix B, Fig. 3), where points are not completely in the line, but close.

We can conclude that all the assumptions were met and proceed to the main results. Hierarchical Multiple Regression analysis was used to test if L2 proficiency, L2 use, L3 proficiency and L3 use (Model 2) significantly predicted participant's visuospatial WM performance, in addition, participant's fluid intelligence and SES were controlled for by introducing them to the analysis first and in a separate block (Model 1). A significant regression equation was found for the Model 1 ($F(2, 35) = 6.26, p = .005$), with an R^2 of .26, where 26% of the variance was explained by predictors (fluid intelligence and SES). It was found that SES ($\beta = .36, p = .024$) but not fluid intelligence ($\beta = .26, p = .097$) had a significant contribution to the fit of the model. Model 2 did not significantly predict visuospatial WM outcomes ($F(6, 31) = 2.33, p = .057$), with an R^2 of .31, explaining 5% of the variance after fluid intelligence and SES was controlled for. None of the variables significantly predicted visuospatial WM: L2 proficiency ($\beta = -.01, p = .956$), L2 use ($\beta = .002, p = .990$), L3 proficiency ($\beta = -.24, p = .209$), L3 use ($\beta = .02, p = .922$).

3.2 Auditory working memory

Similarly to the analysis of the visuospatial WM, when performing Hierarchical Multiple Regression analysis to investigate possible effects of L3 use and proficiency following assumptions should be checked for:

- No outliers. The analysis of standard residuals was carried out including Mahalanobis distance and Cook's distance, which showed that data contained no outliers (*Mahal. distance Max = 14.74; Cook's distance Max = .31*);
- No multicollinearity. Tests that were performed to see if the assumption of collinearity was met indicate that in this analysis multicollinearity was not a concern (Fluid intelligence, *Tolerance = .78, VIF = 1.28*; SES, *Tolerance = .77, VIF = 1.31*; L2 proficiency, *Tolerance = .71, VIF = 1.41*; L2 use, *Tolerance = .66, VIF = 1.28*; L3 proficiency, *Tolerance = .64, VIF = 1.57*; L3 use, *Tolerance = .63, VIF = 1.58*);
- The linearity, homogeneity and normality. The scatterplot of standardised residuals (Appendix B, Fig. 4) showed that the data met the assumptions of homogeneity of variance and linearity. Although by looking at the normal P-P plot of standardised residuals (Appendix B, Fig. 6; points are not completely in the line, but close) we can assume that the data is normally distributed, it is not the case with the histogram of standardised residuals (Appendix B, Fig. 5) which indicates that the assumption of normality was violated.

	Visuospatial WM	Auditory WM	Fluid intelligence	SES	L2 prof.	L2 use	L3 prof.	L3 use
Visuospatial WM			.382 *	.450 *	.059	-.134	-.249	-.199
Auditory WM			.342	.118	.118	-.213	-.012	-.289
Fluid intelligence	.382 *	.342		.332 *	.037	-.114	-.277	-.297
SES	.450*	.118	.332*		.181	-.153	.078	-.068
L2 prof.	.059	.118	.037	.181		.468*	.067	.145
L2 use	-.134	-.213	-.114	-.153	.468*		.224	.309
L3 prof.	-.249	-.012	-.277	.078	.067	.224		.557*
L3 use	-.199	-.289	-.297	-.068	.145	.309	.557*	

Table 1. Pearson's correlations between variables. Two tailed significances $p < .05$ are indicated with a star.

We can conclude that one of the assumptions was violated, we will proceed to the main results, but recognize that they are less reliable. Hierarchical Multiple Regression analysis was used to test if L2 proficiency, L2 use, L3 proficiency and L3 use (Model 2) significantly predicted participant's auditory WM performance, in addition, participant's fluid intelligence and SES were controlled for by introducing them to the analysis first and in a separate block (Model 1). No significant regression equation was found for the Model 1 ($F(2, 35) = 2.31, p = .114$), with an R^2 of .117, where 12% of the

variance was explained by predictors (fluid intelligence and SES). It was found that neither SES ($\beta = .01, p = .977$) nor fluid intelligence ($\beta = .34, p = .051$) had a significant contribution to the fit of the model. Model 2 did not significantly predict auditory WM outcomes ($F(6, 31) = 2.11, p = .080$), with an R^2 of .29, explaining additional 17% of the variance after fluid intelligence and SES was controlled for. None of the variables significantly predicted auditory WM: L2 proficiency ($\beta = .30, p = .102$), L2 use ($\beta = -.31, p = .106$), L3 proficiency ($\beta = .32, p = .098$), L3 use ($\beta = -.33, p = .095$).

Table 1 presents all the correlations obtained in two Hierarchical Multiple Regression analyses, it is important to keep in mind that those are simple correlations and they do not take into account multiple comparisons issue. Both fluid intelligence and SES are significantly correlated with visuospatial WM measures, however, fluid intelligence and SES are also correlating with each other. The multiple regression analysis revealed that higher SES leads to higher visuospatial WM performance, but once it was taken into account, the effect of fluid intelligence disappears.

4. Discussion

The results of our study did not show any effects of either third language proficiency or third language use on visuospatial or auditory WM capacity when statistically controlling for SES and fluid intelligence. This goes against our hypothesis that the knowledge of the third language positively affects visuospatial working memory outcomes, providing no evidence in support of the idea of multilingualism being more beneficial for the WM performance when compared to bilingualism. Additionally, contrary to the previous studies, our study failed to find any correlations between second language proficiency/use and visuospatial/auditory WM performance.

In line with the previous research it was found that SES significantly predicted participant's visuospatial working memory scores (Salthouse & Pink, 2008; Unsworth, Fukuda, Awh & Vogel, 2014). This contradicts the results by Goriot, Denessen, Bakker & Droop (2015), who found that SES did not significantly influence executive functioning (Goriot, Denessen, Bakker & Droop, 2015: p. 9) and therefore, decided not control for it in their analysis. The correlation between fluid intelligence and visuospatial WM performance was also found, however the effect disappeared when SES was taken into account.

Although the current study did not demonstrate positive effects of multilingualism in the domain of working memory, it cannot be concluded that the aforementioned effects do not exist. Our findings might have been flawed by the limitations of our study. Due to the insufficient temporal and financial resources a small number of participants was tested as well as language proficiency and fluid intelligence measures had reduced sensitivity⁵. The literature on the statistical analysis suggest that there should be at least 20 participants for each independent variable in multiple regression analysis; there were six independent variables in our study, implying that the minimum number of participants that had to be tested is 120, which is beyond the capabilities of the research within the master's thesis.

There were no monolingual controls in our study because it is almost impossible to find monolingual educated Dutch adults in their 20's. The presence of the control group as well as a clear-cut groups of bilinguals and multilinguals could lead to better understanding of the effects of multilingualism on executive functioning and specifically on working memory. The previous research found an extensive

⁵ Short version of RSPM task was used to assess fluid intelligence and self-assessment was used to measure participants' language proficiency.

evidence that supports the idea of bilingualism positively affecting working memory performance (e.g. Morales, Calvo & Bialystok, 2013; Blom, Küntay, Messer, Verhagen & Leseman, 2014), but would the knowledge of the third language promote even better WM outcomes? The results of our study suggest that the answer is "NO", all participants in the current study were highly proficient in their second language⁶ and had a knowledge of the third language to some extent. Speculatively, it is possible that more does not mean better and once individual acquired second language, further L3, L4...Ln learning does not influence WM performance, as the ceiling of cognitive improvement was reached.

In addition, there are different linguistic factors that have to be considered when exploring the area of cognitive advantages of multilingualism, such as: language proficiency, language use, age of acquisition and type of multilingualism. At the end of this chapter we also discuss some problems regarding publication bias that lately has been a topic of the debates in linguistic society.

4.1 Language proficiency

Cummins (1976) argued that bilinguals have to reach a certain level of linguistic competence before the benefits of bilingualism could emerge (Cummins, 1976: p. 2). He notes that studies that found bilingual advantage usually tested balanced bilinguals in a social situation where both L1 and L2 are prestigious and socially important. In contrast, many earlier studies that reported cognitive bilingual disadvantage focused on language minority groups to whom L2 was gradually replacing L1 (less prestigious language), hence leading to unbalanced and insufficient proficiency in both their languages (Cummins, 1976: p. 37).

The effects of language proficiency on WM was examined by Blom, Küntay, Messer, Verhagen & Leseman (2014) who investigated "the predictive value of bilingual proficiency on bilingual children's working memory outcomes" (Blom, Küntay, Messer, Verhagen & Leseman, 2014: p. 109) and found that bilingual proficiency in sequential bilingual Turkish-Dutch children was a significant predictor for the 6-year-olds performance on backwards digit recall task but not for the 5-year-olds. Those findings are in line with Cummins (1976) theory, suggesting that the growth in language proficiency is the most important factor that promote cognitive bilingual advantage. Besides of language proficiency Blom, Küntay, Messer, Verhagen & Leseman (2014) investigated whether mothers' language use at home influenced the WM scores of children and found no effect.

Some studies, however, suggest that proficiency does not play a crucial role in executive control development. A study by Bialystok & Martin (2004) compared cognitive abilities of monolingual and bilingual 5-year-olds and found bilingual cognitive advantage for the children from language minorities, who used their L2 only at school and L1 at home and in community and were less proficient in one of their languages. Another study investigated the effects of bilingualism on executive functioning in children and found that although bilingual children had significantly lower scores on verbal tasks and lower SES than their monolingual peers, they were able to perform as good as monolinguals (Carlson & Meltzoff, 2008). The bilingual advantage emerged when the analysis was statistically controlled for verbal scores, SES and age of participants.

⁶ Self-assessment test indicate that on average, participants gave themselves a rating of 23.4 out of 28 points (7-point scale was used for each measures: reading, listening, writing and speaking and sum was calculated as the participant's proficiency score).

In our study a self-assessment form was used in order to evaluate participants' L2 and L3 proficiency. Although this way of non-native proficiency assessment is often used in linguistic research, it can be highly subjective and biased (MacIntyre, Noels & Clément, 1997; Ross, 1998; Kilman, Zekveld, Hällgren & Rönnberg, 2014). To get more valid estimation of non-native language proficiency of an individual, a standardised language tests should be used. This is only possible if all participants have the same L2 and L3, which was not the case in our study. More objective and sensitive measures of multilingualism are crucial factors in determining whether the effects of multilingualism on working memory performance exist and what is the nature of those effects.

4.2 Language use

Another important factor contributing to the development of cognitive control in multilinguals is daily language use. If the benefits of bilingualism emerge from the fact that bilinguals have to control two or more languages simultaneously, choosing only words in one language and supressing others, it would not be surprising that the frequency of use of those languages have an effect on the cognitive performance.

Goriot, Denessen, Bakker & Droop (2015) studied benefits of bilingualism in German and Turkish language minority groups in the Netherlands; to asses children's bilingualism parents and children were verbally questioned about Dutch and home language daily use. They found bilingual advantage in performance on non-verbal WM and switching tasks, supporting the idea of language use as being an important factor for the development of cognitive benefits.

Based on the research and the literature presented in this and previous ("Language proficiency") section of our paper it seems that the language use is a less important factor influencing executive functioning than language proficiency. However, from the correlations between L2 proficiency/use and L3 proficiency/use presented in Table 1, one might speculate that levels of language proficiency and use might be highly dependent on each other. Indeed, it would be surprising if an individual with no daily non-native language input would be able to maintain high proficiency in a given language. Subsequently, with constant daily input from a non-native language we would expect that the proficiency in that language also rise.

4.3 Age of acquisition and type of multilingualism

The age of non-native language acquisition and type of multilingualism might affect the extent of benefits of multilingualism in cognitive functioning. There are different reasons and settings in which one becomes multilingual: some people are exposed to multiple languages from their birth and grow up multilingual, others learn a language at school in their early teens and apart from classroom never have a chance to use a learned language.

For the first language acquisition studies a Critical Period Hypothesis was popularized by Lenneberg in 1967 (Lenneberg, Chomsky & Marx, 1967). The basic concept behind this hypothesis is that native language should be acquired within a certain life period of an individual (before puberty), otherwise some aspects of the language will never be acquired by the named individual⁷. Studies that

⁷ As an example of Critical Period Hypothesis see the case study of Genie – a girl that was neglected and abused by her parents, who never spoke to her. When she was found by a social worker at the age 13 she did

investigate second language acquisition adopted this hypothesis: Johnson & Newport (1989) studied English proficiency in native Chinese and Korean speakers living in USA and found people who started L2 acquisition in early childhood were able to achieve higher L2 proficiency than those who begin their L2 learning in the adulthood. Amongst the researchers who accepted the Critical Period Hypothesis for second language acquisition, the opinion regarding the underlying mechanism of "earlier is better" differs. Some researchers claim that the differences in early and late language acquisition are due to the brain plasticity in the early stage of life, others suggest that the differences are more psychological: children are less distracted by social and mental stimuli than adults (Stewart, 2003). Alternatively, Bley-Vroman, R. (1988) proposed the Fundamental Difference Hypothesis, which states that the differences in the child and adult L2 acquisition are not due to the differences in their brains, but rather due to different settings in which second language is learned. When acquiring a new language children rely on implicit language acquisition, whereas adults are not able to make use of implicit learning anymore and have to depend on problem-solving mechanisms (DeKeyser, 2000). Another approach in second language acquisition theory implies that there are "sensitive" rather than "critical" periods that differ for different aspects of the language.

Another potentially problematic topic for investigating cognitive benefits of multilingualism is type of participants' multilingualism. Different people acquire or learn foreign languages in different settings. Zhu & Li (2005) summarises the most important factors based on which multilingualism can be distinguished, we present those factors in this paragraph. Based on the order of the acquired languages there can be simultaneous and sequential (sometimes called successive) multilingualism. If the child started acquiring two or more languages at the same time it is referred to as simultaneous multilingualism. Sequential multilingualism implies that one language was acquired first and then another language was added later in the life. In our study all the participants were sequential multilinguals, none of the participants was acquiring more than one language in early childhood and only two participants reported having a significant exposure to the second language at the age three. Multilingualism can also differ based on type of input and context in which non-native language acquisition happened. Children can be exposed to varying qualities and quantities of the input, in some cases it can predict their language proficiency in the future. However, this topic is still an insufficiently researched area and more studies are needed to investigate the exact way in which quality and quantity can affect the outcomes of the language learning (Unsworth, to appear, 2016). The settings in which language was acquired also plays a role: one can learn a new language by receiving formal instructions (in a classroom) or by being exposed to the language and learning it in naturalistic setting (Muñoz, 2008). In our study there was a large variation in the type and quality/quantity of the input participants received during non-native language acquisition. We would expect that those differences in a way non-native language knowledge was obtained could also lead to the differences in working memory performance.

Speculatively, it is possible that there is a certain critical or sensitive period in which L2, L3...Ln has to be acquired for the cognitive benefits to emerge. Participants in our study reported that their first exposure to English language happened around age 3 – 10 ($M = 7.5$) years and they have started learning English at school at the age 9 – 12 ($M = 10.3$) years. The first exposure to the third language occurred when participants were aged 0 – 14 ($M = 9.7$) years and they started learning L3 at school at the ages of 8 – 14 ($M = 12.2$) years. This might have been too late for the multilingualism to affect cognitive functioning of our participants. A study with balanced multilinguals who started acquiring languages at the early stages of life would be able to give more reliable answer on whether or not knowing more than two languages lead to better working memory performance.

not speak any language (Fromkin, Krashen, Curtiss, Rigler & Rigler, 1974). Genie was able to learn words and simple grammatical structures, but her language never fully developed.

4.4 Fluid intelligence

Inconsistently with previous findings (Salthouse & Pink, 2008; Unsworth, Fukuda, Awh & Vogel, 2014), in our study fluid intelligence effect on the working memory performance disappeared once socioeconomic status was taken into account. The reason behind those results might be the fact that due to the time limits⁸ in the current study a short version of Raven's Standard Progressive Matrices test was used. The short version consists of 9 items instead of 60, and although the authors of the test confirmed that the test is valid and the scores obtained in this test were able to predict the outcomes of the full RSPM task (Bilker, Hansen, Brensinger, Richard, Gur & Gur, 2012), no further research was conducted that would support the validity of the short version of the task.

4.5 Publication bias

Not all researchers share the enthusiasm that exists in psycholinguistic community regarding the idea of cognitive benefits of bilingualism. De Bruin, Treccani & Della Sala (2015) investigated publication bias in this area of research and found that studies that support bilingual advantage are more likely to get published in journals than the ones with null or negative results. In addition, researchers often get involved in questionable research practices, such as reporting only studies that show significant positive results or keep adding participants until significance is reached. This gives the wrong impression about the strength of the evidence for positive effects of bilingualism on cognitive capacities of an individual. De Bruin, Treccani & Della Sala (2015) criticised the meta-analysis done by Adesope, Lavin, Thompson & Ungerleider (2010) as being potentially biased. They conclude that although they believe that bilingualism is a positive phenomenon, all the results and studies should be reported in order to get a more clear idea of the extents of bilingual advantage and the conditions in which the cognitive effects of bilingualism can emerge. It is especially important because bilingualism has "enormous societal relevance and implications" (De Bruin, Treccani & Della Sala, 2015: p. 8).

The results of our study are in line with other studies that found no positive effects of bilingualism regarding working memory performance. A review by Bialystok (2009) summarises "the good, the bad and the indifferent" (Bialystok, 2009: p. 3) effects of bilingualism. She reports that the research investigating bilingual advantage in working memory domain gives no clear answer to whether bilingualism positively affects working memory performance or not. Studies that use verbal working memory tasks usually show bilingual disadvantage and studies that use non-verbal tasks show no language group difference or bilingual advantage. In the current study, a visuospatial working memory task was used, it is a non-verbal working memory task. However, the results showed no correlation between L2/L3 proficiency/use and visuospatial WM. Overall, the relationship between multilingualism and working memory is a topic that requires more research. Even though it is clear that working memory is a part of executive functioning, and executive functioning gets an enhancement from multilingual experience, the specific effects of multilingualism on WM performance are still undefined.

⁸ The administration time of the RSPM is 40 to 60 minutes. In the current study the total amount of time per participant was 45 to 60 minutes, during which all the tests should have been completed and all the measures obtained.

5. Conclusions

Benefits of bilingualism is a subject undergoing intense study in linguistic research. It has been found that bilinguals show cognitive advantages when comparing to their monolingual peers. These advantages include enhanced executive control, metalinguistic awareness, memory and working memory domains. However, the number of studies investigating working memory in bilinguals is small and almost no research has been conducted to compare bilinguals and tri-/multilinguals. Our study's aim was to fill in this gap and compare performance of bilingual and multilingual participants in the domain of working memory.

The relationship between third language proficiency/use and visuospatial/auditory working memory performance was examined in the current study. It was hypothesized that the third language proficiency and use will be positively correlated with visuospatial WM performance but not with verbal WM performance. In order to investigate whether the hypothesis was true two hierarchical multiple regression analyses were conducted: one for the visuospatial WM measures as a dependent variable and another for auditory WM measures as a dependent variable, additionally, participant's socioeconomic status, fluid intelligence measures and second language use/proficiency were statistically controlled for. Controlling for SES and fluid intelligence was necessary because previous research found that working memory significantly correlates with those variables and in our investigation it was important to make sure the correlations were due to the effects of multilingualism of participants and not due to background variables.

The results of the first statistical analysis show that there was no correlation between L3 proficiency/use and visuospatial working memory performance when participants' socioeconomic status and fluid intelligence were controlled for. Contrary to the previous studies no correlations between L2 proficiency/use and visuospatial WM were found either. SES and fluid intelligence significantly correlated with visuospatial WM performance, this was in line with our expectations and previous findings. However, SES and fluid intelligence also correlated with each other, multiple regression analysis revealed that when the effect of SES was taking into account the effect of fluid intelligence disappeared. Those results suggest that only SES was significantly predicting participant's visuospatial working memory outcomes. In the second analysis no significant correlations between L2/L3 language proficiency/use and auditory working memory scores were found. In addition, the assumption of the normal distribution of auditory working memory scores was violated, therefore no strong conclusions can be drawn based on those results.

Nonetheless, we are not going make strong conclusions about the absence of cognitive benefits of multilingualism in the domain of working memory based on the results obtained in our study. Previous studies found the evidence for benefits of bilingualism in this domain and our study failed to replicate it: no correlations between second language proficiency/use and working memory outcomes were found. Consequently, the absence of the correlations between third language proficiency/use and working memory might not be a sign that the mentioned effect does not exist, it might simply indicate that our study was flawed. And indeed, this research within the resource limits of master's thesis had a reduced power due to the small number of participants as well as less sensitive measures of the variables of interest. The weaknesses of the current study are broadly examined in the Discussion section above. More research is needed to understand the effect of multilingualism on the human cognition in general and working memory in particular.

References

- Adesope, O. O., Lavin, T., Thompson, T., & Ungerleider, C. (2010). A systematic review and meta-analysis of the cognitive correlates of bilingualism. *Review of Educational Research*, 80(2), 207-245.
- Alladi, S., Bak, T. H., Duggirala, V., Surampudi, B., Shailaja, M., Shukla, A. K., Chaudhuri, J. R., & Kaul, S. (2013). Bilingualism delays age at onset of dementia, independent of education and immigration status. *Neurology*, 81(22), 1938-1944.
- Altarriba, J., & Isurin, L. (2013). *Memory, language, and bilingualism: theoretical and applied approaches*. Cambridge: Cambridge University Press.
- Ardila, A. (2003). Language representation and working memory with bilinguals. *Journal of Communication Disorders*, 36, 233-240.
- Arsenian, S. (1945). Bilingualism in the post-war world. *Psychological Bulletin*, 42(2), 65.
- Arthur, W., & Day, D. V. (1994). Development of a short form for the Raven Advanced Progressive Matrices Test. *Educational and Psychological Measurement*, 54(2), 394-403.
- Atkinson, R. C., & Shiffrin, R. M. (1968). Human memory: A proposed system and its control processes. *Psychology of Learning and Motivation*, 2, 89-195.
- Baddeley, A. D., & Hitch, G. (1974). Working memory. *The Psychology of Learning and Motivation*, 8, 47-89.
- Baddeley, A. D., Papagno, C., & Vallar, G. (1988). When long-term learning depends on short-term storage. *Journal of memory and language*, 27(5), 586-595.
- Baddeley, A. D. (2000). The episodic buffer: A new component of working memory? *Trends in Cognitive Sciences*, 4, 417-423.
- Baddeley, A. (2003). Working memory and language: an overview. *Journal of Communication Disorders*, 36, 189-208.
- Bak, T. H., Nissan, J. J., Allerhand, M. M., & Deary, I. J. (2014). Does bilingualism influence cognitive aging? *Annals of Neurology*, 75(6), 959-963.
- Bley-Vroman, R. (1988). The fundamental character of foreign language learning. In W. Rutherford & M. Sharwood-Smith (Eds.), *Grammar and second language teaching: A book of readings* (pp. 19-30). New York: Newbury House/ Harper and Row.
- Bialystok, E., & Martin, M. M. (2004). Attention and inhibition in bilingual children: Evidence from the dimensional change card sort task. *Developmental Science*, 7(3), 325-339.
- Bialystok, E., Craik, F. I., & Freedman, M. (2007). Bilingualism as a protection against the onset of symptoms of dementia. *Neuropsychologia*, 45(2), 459-464.
- Bialystok, E., Craik, F., & Luk, G. (2008). Cognitive control and lexical access in younger and older bilinguals. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 34(4), 859.
- Bialystok, E. (2009). Bilingualism: The good, the bad, and the indifferent. *Bilingualism: Language and Cognition*, 12(01), 3-11.
- Bialystok, E. (2010). Global-local and trail-making tasks by monolingual and bilingual children: Beyond inhibition. *Developmental Psychology*, 46(1), 93-105.

- Bialystok, E. (2011a). Reshaping the mind: the benefits of bilingualism. *Canadian Journal of Experimental Psychology/Revue Canadienne de Psychologie Expérimentale*, 65(4), 229.
- Bialystok, E. (2011b). Coordination of executive functions in monolingual and bilingual children. *Journal of Experimental Child Psychology*, 110(3), 461-468.
- Bialystok, E., Kroll, J. F., Green, D. W., MacWhinney, B., & Craik, F. I. (2015). Publication Bias and the Validity of Evidence What's the Connection? *Psychological Science*, 1-3. (doi:10.1177/0956797615573759)
- Bilker, W. B., Hansen, J. A., Brensinger, C. M., Richard, J., Gur, R. E., & Gur, R. C. (2012). Development of abbreviated nine-item forms of the Raven's Standard Progressive Matrices Test. *Assessment*, 19(3) 354-369.
- Blom, E., Küntay, A. C., Messer, M., Verhagen, J., & Leseman, P. (2014). The benefits of being bilingual: Working memory in bilingual Turkish–Dutch children. *Journal of Experimental Child Psychology*, 128, 105-119.
- Brito, N. H., Grenell, A., & Barr, R. (2014). Specificity of the bilingual advantage for memory: examining cued recall, generalization, and working memory in monolingual, bilingual, and trilingual toddlers. *Frontiers in Psychology*, 5, 1-12.
- Bunge, S. A., Dudukovic, N. M., Thomason, M. E., Vaidya, C. J., & Gabrieli, J. D. (2002). Immature frontal lobe contributions to cognitive control in children: evidence from fMRI. *Neuron*, 33(2), 301-311.
- Carlson, S. M., & Meltzoff, A. N. (2008). Bilingual experience and executive functioning in young children. *Developmental Science*, 11(2), 282-298.
- Chertkow, H., Whitehead, V., Phillips, N., Wolfson, C., Atherton, J., & Bergman, H. (2010). Multilingualism (but not always bilingualism) delays the onset of Alzheimer disease: evidence from a bilingual community. *Alzheimer Disease & Associated Disorders*, 24(2), 118-125.
- Cleveland, M., Laroche, M., & Papadopoulos, N. (2015). You are what you speak? Globalization, multilingualism, consumer dispositions and consumption. *Journal of Business Research*, 68(3), 542-552.
- Cowan, N. (1998). *Attention and memory: An integrated framework*. Oxford: Oxford University Press.
- Corsi, P. M. (1972). *Human memory and the medial temporal lobe region of the brain*. Unpublished PhD thesis, McGill University, Montreal.
- Craik, F. I., Bialystok, E., & Freedman, M. (2010). Delaying the onset of Alzheimer disease Bilingualism as a form of cognitive reserve. *Neurology*, 75(19), 1726-1729.
- Cummins, J. (1976). The Influence of Bilingualism on Cognitive Growth: A Synthesis of Research Findings and Explanatory Hypotheses. Working Papers on Bilingualism, No. 9. Retrieved October 26, 2016, from ERIC Institute of Educational Sciences Web site: <http://files.eric.ed.gov/fulltext/ED125311.pdf>
- Daneman, M., & Carpenter, P. A. (1980). Individual differences in working memory and reading. *Journal of Verbal Learning and Verbal Behaviour*, 19(4), 450-466.
- Darcy, N. T. (1946). The effect of bilingualism upon the measurement of the intelligence of children of preschool age. *Journal of Educational Psychology*, 37(1), 21.

- de Bruin, A., Treccani, B., & Della Sala, S. (2015). Cognitive advantage in bilingualism an example of publication bias?. *Psychological Science*, 26(1), 99-107.
- DeKeyser, R. M. (2000). The robustness of critical period effects in second language acquisition. *Studies in Second Language Acquisition*, 22(04), 499-533.
- Della Sala, S., Gray, C., Baddeley, A., Allamano, N., & Wilson, L. (1999). Pattern span: a tool for unwelding visuo-spatial memory. *Neuropsychologia*, 37(10), 1189-1199.
- Dijkstra, T., Grainger, J., & Van Heuven, W. J. (1999). Recognition of cognates and interlingual homographs: The neglected role of phonology. *Journal of Memory and Language*, 41(4), 496-518.
- Doiz, A., Lasagabaster, D., & Sierra, J. (2013). Globalisation, internationalisation, multilingualism and linguistic strains in higher education. *Studies in Higher Education*, 38(9), 1407-1421.
- Engel de Abreu, P. M. (2011). Working memory in multilingual children: Is there a bilingual effect? *Memory*, 19(5), 529-537.
- Ericsson, K. A., & Kintsch, W. (1995). Long-term working memory. *Psychological Review*, 102(2), 211.
- Esposito, A. G., Baker-Ward, L., & Mueller, S. T. (2013). Interference suppression vs. response inhibition: An explanation for the absence of a bilingual advantage in preschoolers' Stroop task performance. *Cognitive Development*, 28(4), 354-363.
- Fromkin, V., Krashen, S., Curtiss, S., Rigler, D., & Rigler, M. (1974). The development of language in Genie: a case of language acquisition beyond the "critical period". *Brain and Language*, 1(1), 81-107.
- Gathercole, S. E., & Baddeley, A. D. (1989). Evaluation of the role of phonological STM in the development of vocabulary in children: A longitudinal study. *Journal of Memory and Language*, 28(2), 200-213.
- Goriot, C., Denessen, E., Bakker, J., & Droop, M. (2015). Benefits of being bilingual? The relationship between pupils' perceptions of teachers' appreciation of their home language and executive functioning. *International Journal of Bilingualism*, 1-14. (doi:10.1177/1367006915586470)
- Green, D. W. (1998). Mental control of the bilingual lexico-semantic system. *Bilingualism: Language and Cognition*, 1(02), 67-81.
- Hackman, D. A., Betancourt, L. M., Gallop, R., Romer, D., Brodsky, N. L., Hurt, H., & Farah, M. J. (2014). Mapping the trajectory of socioeconomic disparity in working memory: parental and neighborhood factors. *Child Development*, 85(4), 1433-1445.
- Hamel, R., & Schmittmann, V. D. (2006). The 20-minute version as a predictor of the Raven Advanced Progressive Matrices Test. *Educational and Psychological Measurement*, 66(6), 1039-1046.
- Jaeggi, S. M., Buschkuhl, M., Jonides, J., & Perrig, W. J. (2008). Improving fluid intelligence with training on working memory. *Proceedings of the National Academy of Sciences*, 105(19), 6829-6833.
- Jeffries, S., & Everatt, J. (2004). Working memory: its role in dyslexia and other specific learning difficulties. *Dyslexia*, 10(3), 196-214.
- Johnson, J. S., & Newport, E. L. (1989). Critical period effects in second language learning: The influence of maturational state on the acquisition of English as a second language. *Cognitive Psychology*, 21(1), 60-99.

- Kessels, R. P., Van Zandvoort, M. J., Postma, A., Kappelle, L. J., & De Haan, E. H. (2000). The Corsi block-tapping task: standardization and normative data. *Applied Neuropsychology*, 7(4), 252-258.
- Kilman, L., Zekveld, A., Hällgren, M., & Rönnberg, J. (2014). The influence of non-native language proficiency on speech perception performance. *Frontiers in Psychology*, 5(651), 1-9.
- Kormi-Nouri, R., Moniri, S., & Nilsson, L. G. (2003). Episodic and semantic memory in bilingual and monolingual children. *Scandinavian Journal of Psychology*, 44(1), 47-54.
- Kroll, J. F. (2008). Juggling two languages in one mind. *Psychological Science Agenda, American Psychological Association*, 22(1).
- Laurie, S. S. (1889). *Lectures on language and linguistic method in the school: delivered in the University of Cambridge, Easter term, 1889*. Edinburgh: Oliver & Boyd.
- Lenneberg, E. H., Chomsky, N., & Marx, O. (1967). *Biological foundations of language* (Vol. 68). New York: Wiley.
- Linck, J. A., Osthuis, P., Koeth, J. T., & Bunting, M. F. (2014). Working memory and second language comprehension and production: A meta-analysis. *Psychonomic Bulletin & Review*, 21(4), 861-883.
- Luo, L., Craik, F. I., Moreno, S., & Bialystok, E. (2013). Bilingualism interacts with domain in a working memory task: Evidence from aging. *Psychology and Aging*, 28(1), 28-34.
- MacIntyre, P. D., Noels, K. A., & Clément, R. (1997). Biases in self-ratings of second language proficiency: The role of language anxiety. *Language Learning*, 47(2), 265-287.
- Matser, A. (2016) *Statistical Learning: the Relationship Between Seeing Patterns and Speaking Languages*. Unpublished master's thesis, University of Groningen, Groningen.
- McLeod, S. A. (2007). Multi Store Model of Memory - Atkinson and Shiffrin, 1968. Retrieved October 26, 2016, from Simply Psychology Web site: www.simplypsychology.org/multi-store.html
- McLeod, S. A. (2012). Working Memory. Retrieved October 26, 2016, from Simply Psychology Web site: www.simplypsychology.org/working%20memory.html
- Morales, J., Calvo, A., & Bialystok, E. (2013). Working memory development in monolingual and bilingual children. *Journal of Experimental Child Psychology*, 114(2), 187-202.
- Muñoz, C. (2008). Symmetries and asymmetries of age effects in naturalistic and instructed L2 learning. *Applied Linguistics*, 29(4), 578-596.
- Navon, D. (1977). Forest before trees: The precedence of global features in visual perception. *Cognitive Psychology*, 9(3), 353-383.
- Noble, K. G., McCandliss, B. D., & Farah, M. J. (2007). Socioeconomic gradients predict individual differences in neurocognitive abilities. *Developmental Science*, 10(4), 464-480.
- Poulin-Dubois, D., Blaye, A., Coutya, J & Bialystok, E. (2011). The effects of bilingualism on toddlers' executive functioning. *Journal of Experimental Child Psychology*, 108(3), 567-579.
- Ransdell, S., Barbier, M. L., & Niit, T. (2006). Metacognitions about language skill and working memory among monolingual and bilingual college students: When does multilingualism matter?. *International Journal of Bilingual Education and Bilingualism*, 9(6), 728-741.

- Raven, J. C. (1974). *Standard Progressive Matrices: Sets A, B, C, D and E; a Non-verbal Test of a Person's Present Capacity for Intellectual Activity; and The Mill Hill Vocabulary Scale; a Definition and Synonym Selection Test of a Person's General Cultural Level Relative to Other People; Standard Scales with Instructions, Key and Norms and Sample Machine-scorable Record Form*. London: Lewis.
- Richardson, J. T. (2007). Measures of short-term memory: a historical review. *Cortex*, 43(5), 635-650.
- Ross, S. (1998). Self-assessment in second language testing: A meta-analysis and analysis of experiential factors. *Language Testing*, 15(1), 1-20.
- Saer, D. J. (1923). The effect of bilingualism on intelligence. *British Journal of Psychology. General Section*, 14(1), 25-38.
- Salthouse, T. A., & Pink, J. E. (2008). Why is working memory related to fluid intelligence?. *Psychonomic Bulletin & Review*, 15(2), 364-371.
- Schuchardt, K., Maehler, C., & Hasselhorn, M. (2008). Working memory deficits in children with specific learning disorders. *Journal of Learning Disabilities*, 41(6), 514-523.
- Stewart, J. M. (2003). Is There a Fundamental Difference? The Availability of Universal Grammar in Child versus Adult Second Language Acquisition. In *Proceedings of the 6th Generative Approaches to Second Language Acquisition Conference (GASLA 2002)* (pp. 308-314).
- Tucker, G. R. (1999). A global perspective on bilingualism and bilingual education. In J. E. Alatis and Ai-Hui Tan (Eds.), *Georgetown University round table on languages and linguistics* (pp. 332-340). Washington DC: Georgetown University Press.
- Ullman, M. T. (2004). Contributions of memory circuits to language: The declarative/procedural model. *Cognition*, 92(1), 231-270.
- Unsworth, N., Fukuda, K., Awh, E., & Vogel, E. K. (2014). Working memory and fluid intelligence: Capacity, attention control, and secondary memory retrieval. *Cognitive Psychology*, 71, 1-26.
- Unsworth, S. (to appear, 2016). Quantity and quality of language input in bilingual language development. In E. Nicoladis & S. Montanari (Eds.), *Lifespan perspectives on bilingualism* (pp. 136-196). Mouton de Gruyter.
- Woods, D. L., Kishiyama, M. M., Yund, E. W., Herron, T. J., Edwards, B., Poliva, O., Hink, R.F. & Reed, B. (2011). Improving digit span assessment of short-term verbal memory. *Journal of Clinical and Experimental Neuropsychology*, 33(1), 101-111.
- Woumans, E., Santens, P., Sieben, A., Versijpt, J., Stevens, M., & Duyck, W. (2015). Bilingualism delays clinical manifestation of Alzheimer's disease. *Bilingualism: Language and Cognition*, 18(03), 568-574.
- Zhu H. & Li W. (2005). Bi- and Multilingual Acquisition. In M. Ball (Ed.), *Clinical Sociolinguistics* (pp. 165-179). Malden, MA: Blackwell.

Appendix A. Language questionnaire

Participant number ____

Vragenlijst talenkennis

Geboortedatum (DD/MM/JJ): _____

Geslacht: M / V

Studie (indien van toepassing): _____

Beginjaar: _____

In welke regio(s) en land(en) heb je tot je zesde gewoond? _____

Welke talen (inclusief dialecten) spraken je ouders of verzorgers tegen je? _____

Geef aan welke talen (inclusief dialecten) je kent en hoe goed je jezelf acht in het spreken, luisteren, lezen en schrijven in elke taal; op een schaal van 1 tot 7 (1 = zeer slecht; 4 = middelmatig; 7 = vloeiend). Geef hier ook aan welke taal of talen je beschouwt als je moedertaal (de taal of talen die je als eerste hebt geleerd).

Taal	Spreken	Luisteren	Lezen	Schrijven	Moedertaal?
Nederlands					
Engels					

Geef aan hoe vaak je een taal gebruikt om te spreken, luisteren, lezen en schrijven; op een schaal van 1 tot 7 (1 = vrijwel nooit, 4 = de helft van de tijd, 7 = vrijwel altijd)

Taal	Spreken	Luisteren	Lezen	Schrijven
Nederlands				
Engels				

Op welke leeftijd ben je voor het eerst in aanraking gekomen met het Engels, bijvoorbeeld via familie of vrienden, op vakantie, of in de media? _____

Op welke leeftijd ben je begonnen Engels te leren op school? _____

Als je een derde taal kent (dus behalve Nederlands of Engels), op welke leeftijd ben je dan voor het eerst in aanraking gekomen met die taal, bijvoorbeeld via familie of vrienden, op vakantie, of in de media? _____

Op welke leeftijd ben je begonnen een derde taal (behalve Nederlands en Engels) te leren op school? _____

Geef aan wat je opleidingsniveau is

Basisschool	VMBO	HAVO	VWO	MBO	HBO	Universiteit	Doctor

Geef aan wat het opleidingsniveau is van je ouder(s) of verzorger(s)

Ouder/verzorger	Basisschool	VMBO	HAVO	VWO	MBO	HBO	Universiteit	Doctor

Is er nog andere informatie over je taalachtergrond die van belang zou kunnen zijn en die niet in deze vragenlijst is opgenomen?

Hartelijk dank!

Alle verstrekte informatie zal strikt vertrouwelijk worden behandeld en bewaard.

Appendix B. Graphs

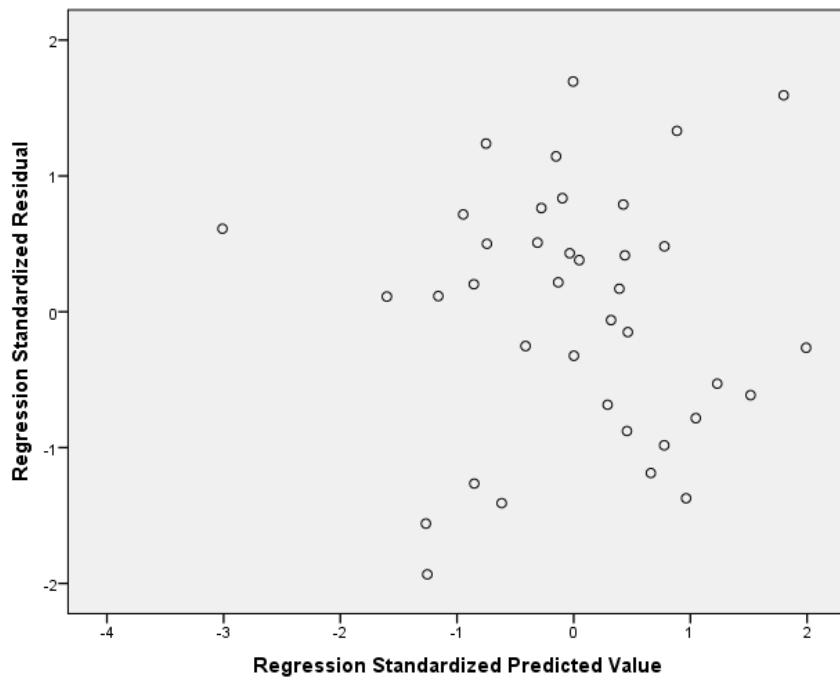


Fig. 1. The scatterplot of standardised residuals for multiple regression analysis with visuospatial WM as a dependent variable.

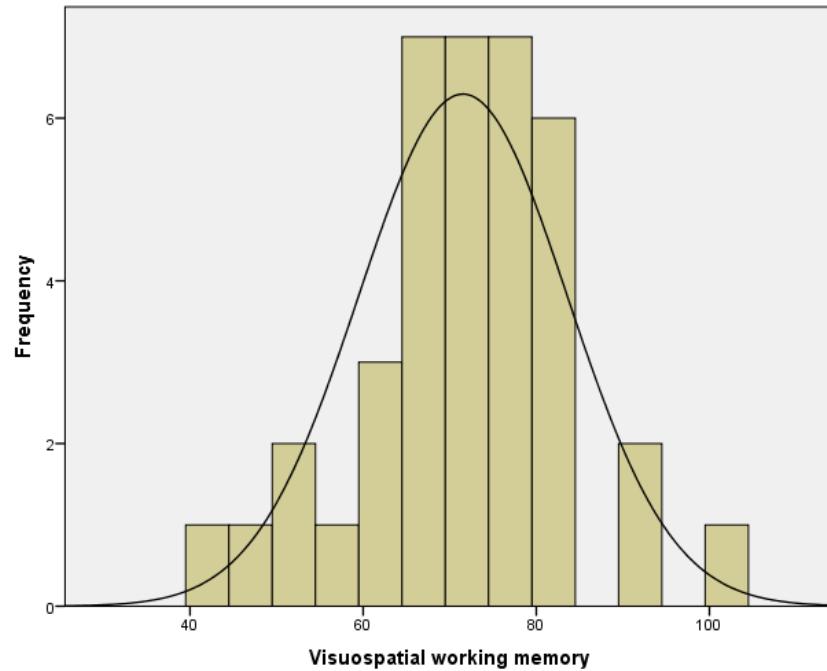


Fig. 2. The histogram of standardised residuals for multiple regression analysis with visuospatial WM as a dependent variable ($M = 71.53$; $SD = 12.03$; $N = 38$).

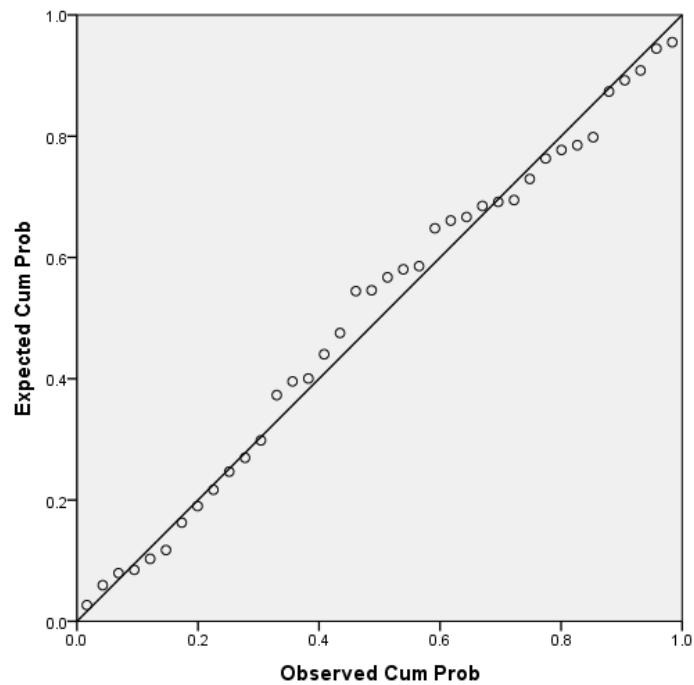


Fig. 3. The normal P-P plot of standardised residuals multiple regression analysis with visuospatial WM as a dependent variable.

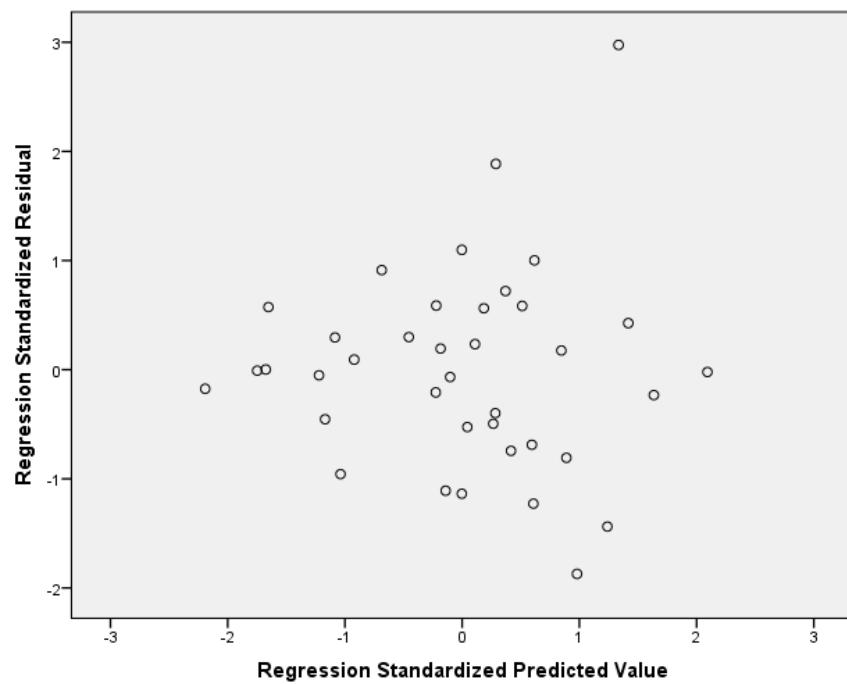


Fig. 4. The scatterplot of standardised residuals for multiple regression analysis with auditory WM as a dependent variable.

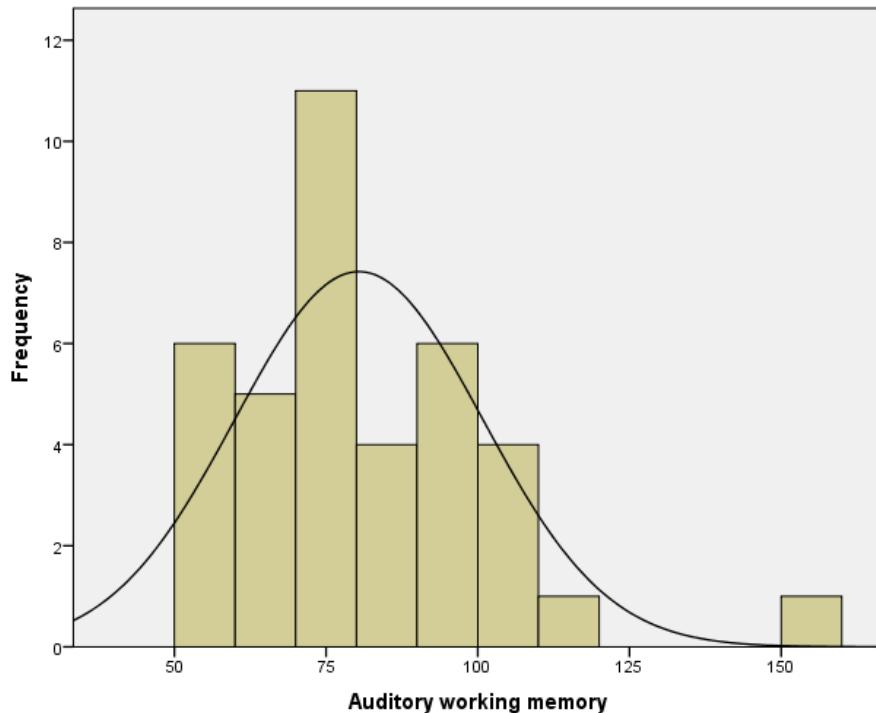


Fig. 5. The histogram of standardised residuals for multiple regression analysis with auditory WM as a dependent variable ($M = 80.39$; $SD = 20.42$; $N = 38$).

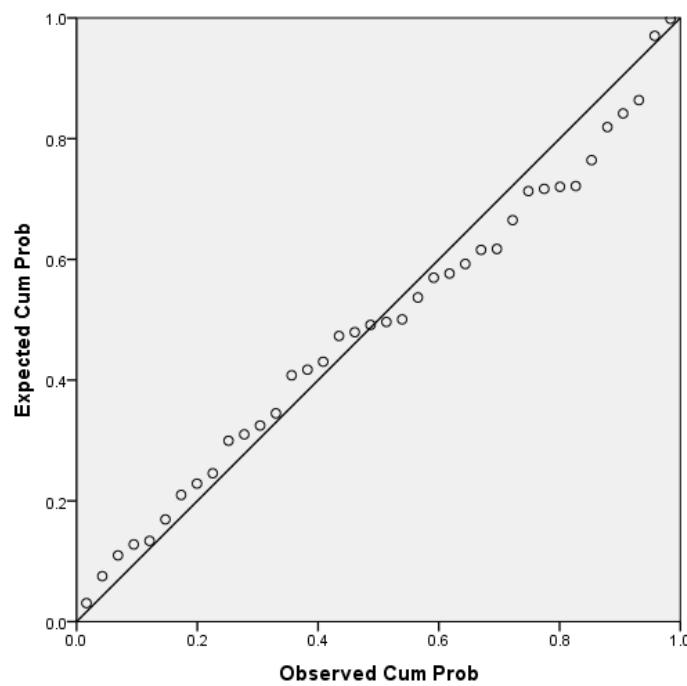


Fig. 6. The normal P-P plot of standardised residuals multiple regression analysis with auditory WM as a dependent variable.