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Working memory performance in bilingual and monolingual adults

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Abstract of Master's Thesis in Psychology

Subject: Psychology	
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Title: Working memory performance between bilingual and monolingual adults	
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Abstract: This study investigated the bilingual executive advantage (BEA) hypothesis in the working memory (WM) domain. A large online sample of 485 adult participants was recruited for the study. The sample was divided into three groups based on language background: 220 monolinguals, 115 early bilinguals and 150 late bilinguals. The participants completed ten separate WM tests and filled out a background questionnaire about language experience and language use. WM was assessed with three composite measures (verbal WM, visuospatial WM, n-back) that were based on a previous latent structure analysis of the WM test battery. Bilingual experience was measured with self-reported age of acquisition, second language proficiency and everyday language switching behavior. Group comparisons revealed that for the n-back composite, late bilinguals outperformed monolinguals on the n-back composite, but monolinguals and early bilinguals did not differ significantly from each other. For verbal and visuospatial WM composites, small but statistically significant differences were found between the bilingual and the monolingual groups, but there is reason to believe that these effects were affected by group differences on background variables. In the bilinguals, hierarchical multiple linear regressions were used to test whether WM performance was associated with some key aspects of bilingual experience. However, none of the regression models could significantly predict for the three WM composites, indicating that either the bilingual experience was not measured adequately or that the group differences were mediated by some uncontrolled variables. All in all, this study did not provide support for the BEA hypothesis. Potential reasons for the controversial outcomes concerning the BEA hypothesis are discussed.	
Keywords: working memory, bilingualism, cognitive ability, bilingual advantage	
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ÅBO AKADEMI – FAKULTETEN FÖR HUMANIORA, PSYKOLOGI OCH TEOLOGI
Sammanfattning av pro gradu-avhandling i psykologi

Ämne: Psykologi	
Författare: Stella Ritamäki	
Avhandlingens titel: Arbetsminnesprestationer hos tvåspråkiga och enspråkiga vuxna	
Handledare: Matti Laine & Karolina Lukasik	
Sammanfattning: Denna studie undersökte det exekutiva försprånget hos tvåspråkiga-hypotesen (EFT) inom arbetsminnesdomänen (AM). Ett stort internetbaserat (online) sampel på 485 vuxna deltagare rekryterades inför studien. Samplet indelades i tre grupper på basis av språkbakgrund: 220 enspråkiga, 115 tidiga tvåspråkiga och 150 sena tvåspråkiga. Deltagarna genomförde sammanlagt tio separata arbetsminnestest och fyllde i ett frågeformulär där de besvarade frågor om sin språkerfarenhet och sitt språkbruk. Arbetsminnesprestationerna bedömdes med hjälp av tre summavariabler (verbalt AM, visuospatialt AM, n-back) som grundade sig i en latent struktur för detta arbetsminnestestbatteri. Tvåspråkighet bedömdes genom självskattad ålder för förvärv av det andra språket, språkkunskapsnivå och språkbytesbeteende. Gruppjämförelsernas visade att de sena tvåspråkiga presterade bättre på n-back jämfört med enspråkiga medan ingen statistiskt signifikant skillnad kunde påvisas mellan de tvåspråkiga grupperna. Därtill kunde små, men signifikanta skillnader påvisas mellan den tvåspråkiga och den enspråkiga gruppen på de verbala och visuospatiala summavariablerna, men det finns orsak att anta de uppstått p.g.a. skillnader i bakgrundsvariabler. Hierarkiska multipla linjära regressionsanalyser genomfördes för att testa sambandet mellan AM och tvåspråkighet hos tvåspråkiga deltagare. Regressionsmodellerna var inte signifikanta för de tre summavariablerna, vilket indikerar att måtten på tvåspråkighet inte var lämpliga eller att gruppskillnaderna uppstod som resultat av okontrollerade variabler. Allt som allt, fick EFT-hypotesen inte stöd i studien. De bakomliggande orsakerna till resultaten och kring den kontroversiella EFT-hypotesen behandlas närmare i avhandlingens diskussionsdel.	
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1 INTRODUCTION

In a modern world with increased migration and mobility across linguistic boundaries, the amount of people speaking more than one language has increased at all levels of society (Bialystok et al., 2009). Today, being bilingual is considered to entail various advantages. For example, bilinguals are able to communicate with a broader group of people which may result in expansion of their social circle and increased opportunities for employment. However, in the past the view on bilingualism was much more negative as learning two or more languages was thought to lead to cognitive disadvantages (e.g. Smith, 1923). This changed when Peal and Lambert (1962) addressed some of the methodological issues in previous research (e.g. controlling for experimental confounds) and found instead that bilingualism appeared to be associated with cognitive advantages.

The cognitive benefits that bilinguals could have over monolinguals have thereafter been of great interest in research and are currently a topic of intense scientific debate. Early research that examined particularly the relationships between bilingualism and executive functions presented a more or less cohesive picture of the bilingual executive advantage (BEA) where bilinguals outperformed monolinguals on various cognitive tasks purported to measure executive functioning (e.g., Bialystok, 2001, 2009; Bialystok, Martin, & Viswanathan, 2005). For example, it was found that bilinguals outperformed monolinguals on tasks that require inhibition of task-irrelevant information (Bialystok & Martin, 2004; Bialystok et al., 2004; Carlson & Meltzoff, 2008; Costa, Hernández & Sebastián-Gallés, 2008; Bialystok & Viswanathan, 2009, Soveri, Rodriguez-Fornells & Laine, 2011) and on other measures of cognitive control (Bialystok & Viswanathan; Costa, Hernández, Costa-Faidella & Sebastián-Gallés, 2009). In addition, bilinguals have been reported to display better ability to store information in working memory

(Bialystok et al., 2004). According to the results of the first meta-analysis on this topic by Adesope and colleagues (2010), bilingualism was positively associated with a range of cognitive benefits. Bilinguals were reported to outperform monolinguals on the combined measures of metalinguistic and metacognitive awareness, measures of abstract and symbolic representation, attentional control, problem solving and WM.

However, especially the more recent empirical evidence is contradictory, including negative meta-analytic findings concerning BEA. The large meta-analysis by Lehtonen and colleagues (2018) found no evidence for bilingual adults outperforming monolingual adults on cognitive control functions after correcting for publication bias. Compared to other similar meta-analytic studies, they also included unpublished data and analyzed task-, participant-, and study-related moderator variables that could affect BEA.

The idea behind the BEA hypothesis (Bialystok et al., 2004) is that the use of two languages is beneficial for executive functioning because of the need to exert language control (Bialystok, 2011). This language control aspects of bilingual language processing have been highlighted in psycholinguistic experiments showing activation of lexical representations in both languages among bilinguals in comprehension tasks, and especially in the production of speech where between-language competition and language switching costs have been found (Marian & Spivey, 2003; Kroll et al., 2006; Hermans, Ormel, Van Besselaar & Van Hell, 2011; Poarch & Van Hell, 2012). These findings suggest that even in a monolingual context, bilingual individuals manage their both languages actively (for a review, see Dijkstra, 2005). The cognitive advantages of bilingualism are thus assumed to result from bilinguals having to monitor their language production system to choose the relevant language and inhibit any intrusions from the non-target language (Green, 1998; Meuter and Allport, 1999; Rodriguez-Fornells et al., 2006; Abutalebi and Green, 2007; Moreno et al., 2008; Bialystok et al., 2009; Ye and Zhou, 2009).

Language control would thus make use of the same general executive mechanisms of inhibition, shifting and monitoring that are outlined in Miyake and Friedman´s model on executive functions (Miyake et al., 2000). Some studies suggest that executive functions can be improved by training (Karbach & Kray, 2009; Mowszowski et al., 2016), and the continuous use of two languages has been suggested as a form of naturalistic EF training (e.g. Stocco, Yamasaki, Natalenko & Prat, 2014; Bialystok, 2017). Enhanced language control in bilinguals could thereby be thought to also translate into enhanced performance on tasks that require executive functions (Antón, Carreiras & Duñabeitia, 2019).

In the domain of working memory (WM) that is at focus here, bilinguals have been found to perform better compared to monolinguals, as high-order executive functions and working memory are closely related (e.g. Engle, 2002; Miyake & Friedman, 2012). It has also been argued that WM resources are required to handle the steady competition for language selection in a bilingual mind, which could enhance WM capacity over time (Bialystok et al., 2004; Bialystok, Craik, & Luk 2008; Fernandes, Craik, Bialystok, & Kreuger, 2007; Michael & Gollan, 2005). However, it has also been proposed that the heavy verbal load from two constantly activated languages could lead to a bilingual disadvantage in terms of WM function (Tokowicz, Michael & Kroll, 2004). Thus, this specific research area is currently in a state of controversy. To further address the putative BEA in the WM domain, the present study examined the differences in WM performance in a large sample of bilingual and monolingual adults.

1.1 The role of working memory in cognition and language learning

WM represents a temporary capacity-limited storage system that enables us to retain and manipulate information in mind. WM is more than just a memory system: it consists of a storage unit for information as well as attentional control directed to this information (Conway et al., 2007). These executive control mechanisms differentiate WM from the older concept of short-term memory (ibid., 2007).

The most influential model of WM is the multi-component model presented by Baddeley and Hitch (1974, revised by Baddeley in 2000 and by Baddeley, Allen, & Hitch in 2011). It consists of two temporary storage systems: one for phonological information (the phonological loop), and the other for visuospatial information (the visuospatial sketchpad) (Baddeley, 2010). The third subsystem, the central executive, coordinates the information used in the phonological loop and visuospatial sketchpad and controls the focus of attention (Blasiman & Was, 2018). Later on, the episodic buffer has been considered as a fourth WM subsystem (Baddeley, 2000). It stores chunks of visual and auditory information, and links the phonological loop and the visuospatial sketchpad to long-term memory (Baddeley, 2007).

WM is traditionally considered to consist of neurally and behaviorally separate storage and processing mechanisms (Baddeley and Hitch, 1974; Baddeley, 1986; Eriksson, Vogel, Lansner, Bergström & Nyberg, 2015), and it has been argued that tests of WM should therefore engage both of these mechanisms (Cowan et al., 2007).

WM enables us to monitor ongoing cognitive processes by engaging selective attention to relevant representations, and by suppressing irrelevant, distracting ones (Oberauer et al., 2003). WM capacity has been demonstrated to correlate with higher-order cognitive activities such as fluid intelligence (Conway et al., 2013). WM is thus considered to be a mental space where cognition and thinking occurs (Baars & Franklin, 2003). WM also facilitates ongoing cognitive

operations such as reasoning, comprehension, problem solving and learning (Cowan, 2010; Cowan, 2014) and has been shown to positively predict performance on cognitive tasks and outcomes such as academic success (Alloway & Alloway, 2010), reading comprehension (Swanson & Alloway, 2012) and mathematical ability (Friso-van den Bos, van der Ven, Kroesbergen & van Luit, 2013).

WM is also suggested to play a critical role in language learning and comprehension, and better WM has been associated with various language outcomes such as writing development (Bourke, Davies, Sumner & Green, 2013), vocabulary learning (Atkins & Baddeley, 1998), oral fluency development (O'Brien, Segalowitz, Freed, & Collentine, 2007), as well as reading and listening comprehension (Jiang & Farquharson, 2018). WM performance is strongly mediated by executive control and especially for second language (L2) speakers that have not yet achieved mastery in their L2, L2 processing puts high demands on these cognitive control mechanisms. Thus, there is evidence that WM plays an important role in L2 processing and in the development of L2 proficiency (Linck, Osthus, Koeth & Bunting, 2014). L2 processing and proficiency outcomes are therefore suggested to reflect WM capacity.

Nonetheless, in BEA research the repeated use of two languages is suggested to impact executive functioning. Thus, the directional relationship between WM and L2 outcomes is not yet fully understood (Linck et al., 2014).

1.2 Defining bilingualism

Bilingualism is not a categorical variable, but rather a sum of individual and dynamic experiences. In the literature, it has received various definitions. Some scholars have used the term to describe "native like mastery of two languages" (e.g. Bloomfield, 1935) whereas others have defined bilingualism as the use of two languages without any proficiency requirements

(Mackey, 1962). Classifications of bilinguals can also be made on the basis of age of L2 acquisition, simultaneity of L2 acquisition (simultaneous vs. sequential bilinguals), proficiency, or frequency of L2 use (active vs. latent bilinguals) (Calvo, García, Manoiloff & Ibáñez, 2016).

This variability in defining bilingualism poses methodological and conceptual challenges when it comes to BEA research (Luk & Bialystok, 2013). Currently, there is no accepted standard for defining who is bilingual nor a clearly defined line between bilingual and monolingual experience (Luk & Bialystok, 2013). Thus, researchers have not yet developed an objective, commonly accepted way of measuring bilingualism (Carlson & Meltzoff, 2008). Generally, the criterion for bilingualism is sufficient proficiency in two or more languages, albeit it is challenging to define the sufficient skill level to be considered bilingual (Carroll, 2017). Along these lines, some scholars have suggested ”usage” instead of ”proficiency” as a more reliable indicator for bilingualism (Grosjean, 2013).

Another methodological challenge that has been discussed is the variability within groups of participants in studies of bilingualism (e.g. Hulstijn, 2012; Luk & Bialystok, 2013). Participants selected for studies show variation in language proficiency, language acquisition history and current usage of their first and second language, which leads to difficulties in generalizing findings (Luk & Bialystok, 2013).

Since bilingualism is a dynamic life experience and balanced bilingualism is a rare phenomenon (Luk & Bialystok, 2013), a broad definition on bilingualism was used in the present study. Bilingualism was defined as *the ability to speak two languages without any requirements of AoA, proficiency or recent language use*, even though these factors were acknowledged. The broad definition also made it possible to investigate the relationship between features of bilingual experience and working memory.

1.3 Bilingualism and language switching

Bilingual language use, and the competition between languages, has been suggested to train executive functions and enhance cognitive control over time (e.g. Bialystok, Craik, Klein & Viswanathan, 2004; Bialystok, 2017). Switching between languages is assumed to enhance general set-shifting and monitoring, as well as general inhibition as the bilingual tries to avoid interference from the non-target language (Linck, Schwieter & Sunderman, 2012).

Evidence from neuroimaging studies suggests that bilingual language control involves the same brain regions that are engaged by general executive function tasks. These regions include the anterior cingulate cortex and dorsolateral prefrontal cortex (Abutalebi et al., 2007; Abutalebi & Green, 2008; Van Heuven et al., 2008; Abutalebi et al., 2012; Luk et al., 2012). While general executive function tasks and language switching engage overlapping neuroanatomical regions, this does not necessarily mean that their neural instantiations are identical. According to Paap (2014) and colleagues (e.g. Paap, Johnson & Sawi, 2014, 2015; Paap & Liu, 2014), behavioural differences in bilinguals vs. monolinguals need to align with neural differences to be interpreted as a "bilingual advantage". Due to the small number of behavioural studies investigating the association between general EF and language switching, this relationship is not yet well understood.

1.4 Relationships between features of bilingual experience and cognitive performance

Putative BEA has usually been studied by comparing bilinguals to a monolingual group. A complementary correlative approach entails the study of associations between key features of bilingual experience and cognitive measures. Such features include AoA, L2 proficiency and everyday language switching. For example, if BEA holds, one could expect that AoA would be positively associated with executive performance, since bilinguals who acquired their L2 earlier

in life would have obtained more everyday training in managing two languages simultaneously which is assumed as a basis for the BEA (Luk, de Sa & Bialystok, 2011). Furthermore, bilinguals highly proficient in their L2 might have to manage interference from their L2 whilst using their L1, which could enhance cognitive control over time (Luo, Luk & Bialystok, 2010). On the other hand, the same could be true for bilinguals with lower L2 proficiency who would need to suppress the impulses of using their L1 when speaking their L2 (Linck, Hoshino, & Kroll, 2008). The third bilingualism-related feature, switching from one language to another, requires both activation of the language in use and inhibition of the language not in use, which could lead to enhanced performance in the executive domain (Soveri, Rodriguez-Fornells & Laine, 2011).

To this date, there is only a limited number of studies exploring the associations between the features of bilingual experience and working memory performance. Vejnović, Milin and Zdravković (2010) conducted a study where they investigated how AoA and language proficiency was related to verbal working memory performance in bilinguals. The results revealed that early bilinguals performed better in the L2 running memory span task compared to late bilinguals, and a larger L1 than L2 span was exhibited also in bilinguals who acquired their L2 early on. Blom and colleagues (2014) additionally discovered that a higher bilingual proficiency was associated with a better backward digit recall performance in bilingual 6-year-old children.

Studies on language switching, on the other hand, have failed to show a clear pattern of associations between everyday language switching and working memory performance (e.g. Paap et al., 2017; Soveri et al., 2011). The study by Jylkkä and colleagues (2017) showed results contrary to BEA, as adult bilinguals who made more unintended language switches also performed worse on WM updating as measured by the n-back task. There is thus reason to further examine whether key features of bilingual experience correlate with executive functions.

1.5 Meta-analyses on the relationships between bilingualism and cognitive performance, with particular emphasis on WM

As noted above, studies examining the putative bilingual executive advantage have yielded conflicting findings, thus prompting the use of meta-analyses. As of now, eight meta-analyses examining the relationships between bilingualism and executive functions have been published (Adesope et al., 2010; Linck et al., 2014; De Bruin et al., 2015; Donnelly, 2016; Grundy & Timmer, 2017; Von Bastian et al., 2017; Lehtonen et al., 2018; Donnelly et al., 2019). The results from these meta-analyses are mixed. Some meta-analyses show a significant, but small positive effects favoring bilinguals on cognitive performance measures (Adesope et al., 2010; de Bruin et al., 2015; Donnelly, 2016; Grundy & Timmer, 2017), while the more recent meta-analyses do not show any significant differences between bilinguals and monolinguals on cognitive task performance (Lehtonen et al., 2018; Donnelly et al., 2019). The meta-analyses are summarized in Table 1 below.

Focusing on the bilingual advantage in executive domains, Adesope and colleagues (2010) performed the first meta-analysis investigating the effects of bilingualism on cognitive measures. Their analysis included studies with samples of both adults and children. Their analysis revealed a moderate overall effect, indicating that bilingualism is associated with positive effects on several cognitive measures, including WM, attentional control, problem solving, metalinguistic and metacognitive awareness and abstract and symbolic representation skills. However, individual studies showed high variability in their results.

Linck and colleagues (2014) conducted a meta-analysis on the connection between WM and L2 processing and proficiency outcomes. Only studies with adult (>18 years old) bilingual samples who learned their L2 after becoming proficient in their native language were included. Their analysis showed a robust positive correlation between the WM and L2 processing and

proficiency development, which could indicate that greater WM capacity leads to a better performance on L2 processing tasks. However, Linck and colleagues (2014) conclude that the causal relationship between WM and L2 measures is still unknown and requires further investigation.

De Bruin and colleagues (2015) conducted a meta-analysis comparing performance of bilinguals and monolinguals on executive control tasks. Their analysis revealed a small but significant effect of bilingualism being positively associated with EF. However, de Bruin and colleagues acknowledged that publication bias could affect this bilingual advantage and if also unpublished studies with null or negative effects were included, the effect would diminish.

Donnelly (2016) conducted two meta-analytic studies. Study 1 looked at the effects of bilingualism on interference control. Bilinguals are assumed to exhibit smaller interference costs on tasks tapping interference control, as they practice inhibition with their two languages being simultaneously activated even though only one is being used in a given moment. Over time, this everyday practice should lead to enhanced performance on interference control tasks. As regards the specific measures, interference costs (performance difference between congruent and incongruent trials) are considered to mirror the time that it takes to repress a distractor, while global RT (encompassing both congruent and incongruent trials) is thought to indicate how efficiently one is processing in an environment with conflicts. The results of study 1 showed no main effects of the dependent variable (i.e. global RTs vs. interference cost) or task (Simon, Flanker vs. Stroop tasks). Significant interactions indicated that overall effects were stronger for children compared with younger adults on global reaction times (global RTs), and for older adults when compared to younger adults on interference costs and global RTs. Moreover, the bilingual advantage on global RTs was larger for the bilinguals who had acquired their L2 early in life compared to late bilinguals. Nevertheless, Donnelly noted that these significant interaction effects

could be due to the presence of a publication bias across levels of moderator variables (age and L2 AoA). Study 2 investigated the effect of bilingualism on set shifting, showing no significant effects favoring bilinguals.

Donnelly, Brooks and Homer (2019) recently conducted a similar meta-analysis by comparing bilinguals´ and monolinguals´ performance on non-verbal interference control tasks with the same dependent variables as above, namely global RT and interference cost. Their results revealed a significant but small positive effect of global RT and interference cost favoring the bilingual group. After correcting for publication bias, the effect of global RT was no longer significant. The interference cost showed a very small but significant bilingual advantage which, unexpectedly, was larger for studies with late bilinguals. The authors concluded that their meta-analytic results provide only weak support for the bilingual advantage hypothesis.

In 2017, Grundy and Timmer conducted a meta-analysis on the relationships between bilingualism and WM capacity. They included studies with both children and adults. Grundy and Timmer (2017) reported a significant, small-to-medium population effect size to the bilinguals' advantage when compared with monolinguals. Rosenthal's fail-safe N (1979) was used to assess for publication bias, and it suggested that the population effect size estimate was likely safe from publication bias. Grundy and Timmer (2017) interpreted the difference in WM capacity between bilinguals and monolinguals as the result of managing two languages that compete for selection. They also discussed the results of Linck and colleagues' (2014) meta-analysis and suggested that the correlation between L2 proficiency and WM could go in the other direction so that greater L2 proficiency leads to enhanced WM capacity. The bilingual WM advantage Grundy and Timmer observed was present when bilinguals performed the tasks in their dominant language. However, when bilinguals performed the tasks in their L2, they performed worse compared to monolinguals.

Von Bastian and colleagues (2017) conducted a meta-analysis that revealed a small but statistically significant positive effect of bilingualism on WM performance. However, there was a considerable amount of heterogeneity amongst the studies included. This variability in effect sizes could not be explained by moderators or publication bias.

Lehtonen and colleagues (2018) conducted a meta-analytic review on BEA in adults. Their meta-analysis included six executive domains: attention, inhibitory control, monitoring, shifting, verbal fluency and working memory, thus encompassing more domains than in previous meta-analyses. They included altogether 152 studies that compared the performance of bilingual and monolingual adults on executive tasks. Also unpublished material was included. All in all, the meta-analysis had 891 effect sizes. The results showed statistically significant but very small BEA effects on inhibition, shifting and WM, but these effects disappeared after correcting for publication bias. There was no performance advantage favoring bilinguals for inhibition, monitoring, shifting, attention, or for WM.

To summarize, two meta-analyses have reported BEA in the WM domain (Adesope et al., 2010; Grundy & Timmer, 2017). The most recent meta-analysis by Lehtonen and colleagues (2018), on the other hand, suggests that bilinguals do not have an executive advantage over monolingual individuals in any executive domain, including WM. Thus, the WM-related results from these meta-analyses are inconsistent and require further research.

Table 1
Summary of meta-analyses comparing bilinguals and monolinguals in different executive domains.

Study	Number of studies included	Number of participants and/or effect sizes	Cognitive domains included	Main effect sizes	Main findings and comments
Adesope et al. (2010)	63 studies	6022 participants	Attention control, WM, metalinguistic awareness, metacognitive awareness, abstract/symbolic reasoning, problem solving	g = 0.41, 95% CI [0.36, 0.46]	Moderate positive overall effect of bilingualism on different cognitive measures. Significant variability among studies. Some yielding a positive cognitive effect of bilingualism and others a negative cognitive effect. *Comments*. Risk of publication bias was not statistically significant.
Linck et al. (2014)	79 studies	3707 participants, 748 effect sizes	WM	r = 0.255, 95% CI [0.219, 0.291]	The results show that WM capacity is positively associated with both L2 processing and proficiency outcomes. *Comments*. Risk of publication bias was not statistically significant.
de Bruin et al. (2015)	41 studies	176 effect sizes	Executive control	d = 0.30, 95% CI [0.23, 0.37]	A small positive effect of bilingualism on executive control. *Comments.* Potential publication bias, effects overestimated.
Donnelly (2016)	Study 1: 43 studies Study 2: 10 studies	Study 1: 168 effect sizes Study 2: 30 effect sizes	Study 1: global RT Study 2: set shifting	Study 1: d = 0.29, 95% CI [0.15, 0.44] Study 2: d = -.06 CI [-0.32, 0.20]	Study 1: small positive effect favoring bilinguals. *Comments.* Risk for publication bias, effects overestimated. Study 2: there was no evidence for bilingual advantage on task-switching tasks.

Table 1 (continued)

Summary of meta-analyses comparing bilinguals and monolinguals in different executive domains.

Study	Number of studies included	Number of participants and/or effect sizes	Cognitive domains included	Main effect sizes	Main findings and comments
Grundy & Timmer (2017)	27 studies	2 901 participants, 88 effect sizes	WM	r = 0.20, 95% CI [–0.253, 0.653]	A small to medium effect size showing a greater WM capacity for bilinguals when compared with monolinguals. Effect sizes were largest in bilingual groups that were children. *Comments.* Risk of publication bias was not statistically significant.
Von Bastian et al. (2017)	88 studies	108 comparisons	WM	g = 0.11 CI [0.03, 0.19]	A small but significant effect. Large heterogeneity amongst studies. Studies revealed as many bilingual advantages as disadvantages. *Comments.* Neither moderators nor publication bias could explain variability in effect sizes.
Lehtonen et al. (2018)	152 studies	891 effect sizes	Attention, inhibitory control, monitoring, set shifting, verbal fluency, WM	g = 0.06 CI [0.01, 0.10] After correcting for publication bias g = 0.08 CI [0.17, 0.01]	The results showed a very small positive association between bilingualism and inhibition, shifting, and WM. Small disadvantage for bilinguals on verbal fluency. *Comments.* After correcting for publication bias, the BEA effects disappeared.
Donnelly et al. (2019)	80 studies	253 effect sizes	Conflict monitoring skills	g = 0.13, global RT g = 0.11, interference cost	No effect for global RT after correcting for publication bias. Effect sizes were not significantly moderated by age or task, but were significantly moderated by an interaction between age of L2 acquisition and the dependent variable.

1.6 Controversies surrounding studies on BEA

As previously mentioned, the current body of relevant research does not offer a clear picture of the putative BEA. These mixed findings have led some scholars to question the methodological quality of the studies conducted in the field (e.g. Paap & Sawi, 2014; Duñabeitia & Carreiras, 2015; Calvo et al., 2016; Paap et al., 2016). Criticism has been directed to publications using small sample sizes that entail weaker statistical power (Asendorpf et al., 2013), and the bilingual executive advantage has consequently not been observed in studies with large sample sizes (e.g., Gathercole et al., 2014; Duñabeitia et al., 2014). Some concern has also been raised regarding the natural groups design used in bilingual studies, and the confounding factors that could intervene with measures of executive functions. These variables include, for example, culture (Yang, Yang, & Lust, 2011), education and socioeconomic status (Evans & Shamberg, 2009; Hackmann & Farah, 2009), immigration status (de Bruin, Bak, & Della Sala, 2015), video gaming (e.g. Hutchinson et al., 2016) and music training (e.g. Moreno et al., 2011). Furthermore, criticism has been directed toward the lack of convergent validity of the EF measures used: cross-task correlations between EF tasks that tap the same domain is low (e.g., Miyake et al., 2000; Paap & Greenberg, 2013; Paap & Sawi, 2014; Waris et al., 2017).

In addition, BEA findings have been claimed to be affected by publication bias (Bakker, 2015; Gathercole, 2015; de Bruin & Della Sala, 2015). To investigate this, de Bruin and colleagues (2015) analyzed conference abstracts on bilingualism and executive control (from years 1999–2012) to see which ones were eventually published in journals. This analysis revealed a publication bias favoring studies that support the BEA hypothesis while studies with null or negative findings were published less often (de Bruin, Treccani, & Della Sala, 2015).

1.7 Aims and research questions

The aim of this study was to investigate the relationships between bilingualism and WM performance. More specifically, the study examined whether bilingual adults outperform their monolingual peers in WM tasks, namely measures of verbal WM, visuospatial WM and n-back. Three central bilingualism-related factors were included in the analysis: self-reported age of L2 acquisition (AoA), L2 proficiency and frequency of language switching in everyday life.

The WM measures included three composite measures derived from the latent structure analysis of the present test battery by Waris and colleagues (2017). Compared with earlier studies, some methodological issues were addressed in the present study: the participant groups (monolinguals, early bilinguals and late bilinguals) were diverse and large, the WM battery was extensive, and the WM measures were more reliable composite scores based on the latent structure of this particular test battery. More specifically, the following research questions were addressed:

- **Question 1:** Are there statistically significant differences between bilinguals and monolinguals on WM performance?
- **Question 2:** Are there differences on WM performance between early and late bilinguals?
- **Question 3:** Within bilinguals, are measures of bilingual experience related to WM performance?

2 METHOD

The present data stems from the study by Waris and colleagues (2017) that focused on the latent structure of the WM measures and did not address bilingualism-related questions. For further details, see Waris et al. (2017).

2.1 Ethics Statement

The Joint Ethics Committee at the Department of Psychology and Logopedics, Åbo Akademi University, and the Human Research Review Board at the University of California, Riverside, approved the original study by Waris et al. (2017). All participants gave their informed consent, and they were informed on their right to stop at any time and that they remained anonymous.

2.2 Procedure

Amazon Mechanical Turk (MTurk), a crowdsourcing marketplace, was used to recruit the participants to this study. The recruitment process was restricted to those participants who had completed more than a 100 but less than 1000 work assignments in MTurk. The sample was restricted to participants located in the United States. In order to obtain consistent and satisfactory data quality, the participants were required to have a 95% work approval rating or higher. Each participant could only make a single attempt at the assignment, which was ensured by a HTML scripting tool used for tracking.

The study encompassed a background questionnaire and ten WM tests. The questionnaire and the tasks were administered using an in-house developed web-based platform called SOILE. The experiment was conducted on a computer of the participants´ choosing and access was provided by sending a link to the participants. All participants filled in at first the background questionnaire, and then took the battery of ten WM tests. The WM task paradigms used were as follows: simple span (forward span and backward span), complex span, running memory, and n-

back tasks. For each task, there was a numerical-verbal version and a visuospatial version. The order of the WM tests, except for the forward simple span task, was randomized for the participants. The study took around 1.5 to complete on average, and the participants were reimbursed after completing the study.

2.3 Participants

Altogether 711 American adult participants completed all parts of the study. Fifty-five participants were excluded due to missing values on the tasks (n = 4), reporting the use of external tools such as taking notes during task performance (n = 38), taking over a day (24 hours) to complete the study (n = 1), and/or for being a multivariate outlier on task performance (n = 12). Furthermore, because depressive symptoms may influence WM performance (see Salazar-Villanea et al., 2015), 136 participants who exhibited moderate, severe or very severe symptoms on the Quick Inventory of Depressive Symptomatology (Rush et al., 2003) were excluded. This left a sample of 503 participants.

Further exclusions were made based on the participants' reported L2. Participants who answered "English", "Latin" or gave meaningless answers were excluded from the sample (n = 7), resulting in a sample of 496 participants. Moreover, participants with missing data on L2 age of acquisition (AoA) or L2 proficiency were excluded (n = 11). Thus, the final sample included 485 participants, of whom 265 were bilinguals. Out of these individuals, 115 reported learning their L2 before or at the age of 12, being classified as early bilinguals. The remaining 150 participants reported learning their L2 after the age of 12, and they were classified as late bilinguals. Within the sample of bilinguals, some participants reported proficiency in more than two languages. However, since only L2 use was considered to be relevant for the study, these participants were also categorized as bilinguals. The most commonly reported second languages

amongst the bilingual groups were Spanish (141 speakers), French (41 speakers) and German (20 speakers). All participants included in the sample reported English as their first language (L1), which ensured that both groups (bilinguals and monolinguals) were performing the tests in their dominant language.

2.4 Background questionnaire

The participants' language background and language use were measured by the background questionnaire, which included listing all languages they had learned or studied, and the AoA of each language. Furthermore, the participants were asked to evaluate their proficiency in these languages using a Likert scale ranging from 1 - *Beginner* to 6 - *Mastery*. In addition, the participants were asked to assess their regular language use for the last two years in percent to document the distribution between languages (for example, 60% English and 40% Spanish). Additionally, two questions addressed everyday language switching. Both switching questions included a Likert scale from 1-5. The switching questions were then recoded into one composite variable ranging from 1-5. The language questions and response alternatives are summarized in Table 2.

Table 2

Background questions related to languages used, AoA, language proficiency, features of language use, and language switching

Question	**Response alternatives**
Please list all the languages you have learned/studied (including your native language(s)) and the age at which you started learning them.	Open text box
Also, for each language, please evaluate your proficiency in that language.	1 Beginner 2 Elementary 3 Intermediate 4 Upper Intermediate 5 Advanced 6 Native-level Mastery
In the table below, please indicate which languages you have been using regularly during the last two years. Also, please indicate the approximate percentage of your weekly language use in each language (including speaking, listening, reading, and writing).	Percentage / week Note. Total = 100 %
People who know and use two or more languages often tend to switch or mix between the languages, for example, during a conversation, or from one conversation to another. The following two questions ask you to report your tendency to switch or mix languages in your everyday life. Language switching can take place in both oral and written (for example, email/SMS) language contexts On average, I switch between different languages ___times a day.	0-2 times 3-10 times 11-30 times 31-60 times +60 times
On average, I make several brief language switches during a single day.	Completely agree Somewhat agree Don´t agree or disagree Somewhat disagree Completely disagree

2.5 Working memory tests

The study included a test battery of ten WM tasks, representing four task paradigms: simple span (forward and backward), complex span, running memory, and n-back. All task paradigms included a numerical-verbal variant involving digits 1-9, and a visuospatial variant involving visuospatial locations within a 3×3 grid. In order to minimize the variance caused by stimulus-specific factors, the numerical verbal and visuospatial task variants were created so that they closely resembled each other.

2.5.1 Simple span tasks

Simple span tasks are presumed to tap WM storage (Conway et al., 2005). In simple span tasks, individuals are asked to repeat items in the same order as they have been presented. The lists of stimuli presented varies in length.

In the present study, the simple span tasks comprised of stimulus lists of varying lengths (3-9 items) that were presented in a pseudorandomized order. The stimuli were digits and spatial locations. There were seven trials with one list length per trial. In the forward version, the participants were expected to report the items in the order they had been presented, whereas in the backward version they were to report them in reverse order. Two practice trials were included in all of the tests, but these were not included in the analyses. The dependent measure was the total number of correctly recalled items.

2.5.2 Complex span tasks

Complex span tasks put demands on both WM storage and processing and due to this, they have been introduced as a better measure for WM capacity compared to simple span tasks (Daneman and Carpenter, 1980). Compared to simple span tasks, in complex span tasks a secondary processing demand is inserted between the items that participants have to remember, meaning

that participants have to maintain information in an accessible form during ongoing cognitive activity. This is considered to mirror a more realistic use of the WM system (Bailey, Dunlosky & Kane, 2011).

Similarly, to the simple span tasks, the complex span tasks encompassed stimulus lists of varying lengths (3-7 items), the order of which was pseudorandomized. The participants' task was to recall the target items (either digits or spatial positions in a matrix) in the order they were presented. In the verbal task, the distractor items appearing in-between the targets were arithmetic problems, and in the visuospatial task, they were pattern matrices that one had to combine mentally. The tests comprised of five trials with one list per list length. The dependent measure was the total number of correctly recalled items.

2.5.3 Running memory tasks

In the running memory tasks, the participants had to repeat the n last items of an item sequence. The length of the sequence is unknown to the participant who is therefore required to update the last n items continuously. Running memory tasks are thus traditionally used as a measure of WM updating (Pollack, Johnson & Knaff, 1959).

Similar to the simple and complex span tasks, stimulus lists of varying lengths (4-11 items) were presented in the running memory tasks. The participants had to report the last four items in the order they were shown. Prior to each running memory task (verbal or visuospatial), the participants performed two practice trials. Each task included eight trials, with one trial per list length. The dependent measure was the total number of correctly recalled items.

2.5.4 N-back tasks

The n-back task requires monitoring, updating and manipulation of to-be-remembered stimuli, thus putting a considerable demand on WM (Owen et al., 2005). Especially WM updating is

considered to be important for performance on n-back tasks. In the n-back task, the participants had to decide whether a presented item is identical to an item that was shown n trials previously.

In this study, both 1- and 2-back tasks were included and presented in a random order. In the 1-back task, the participants had to report if the presented item (digit or spatial location) was the same as the immediately preceding item. In the 2-back task, they had to decide if the item was the same as the item presented two items back. Before each n-back task, the participants performed a practice trial. The actual n-back tests included the same number of target items, no-target items and so-called lure items (misleading n+1 or n-1 matches).

Due to the simplicity of the 1-back task, only the results of the 2-back task were used. The dependent measure was the total number of correct hits ("match" responses on target items) minus the total number of false alarms ("match" responses on no-target items).

2.6 Statistical analyses

At first, Pearson´s correlations were conducted to see if age, education and childhood socioeconomic status correlated with WM performance. The two bilingual groups (early and late bilinguals) were compared to each other on L2 proficiency, frequency of L2 use and language switching. To determine the differences in WM performance between the monolinguals and the bilinguals, an ANCOVA was conducted separately for each of the three WM composites using age and education as covariates. One-way ANOVAs were conducted to compare the differences in WM performance between the two bilingual groups, namely early and late bilinguals.

Thereafter, the associations between key features of bilingual experience and the three working memory composites (visuospatial WM, verbal WM and n-back) were assessed by using hierarchical multiple regression analyses. Both early and late bilinguals were included as a single group in these analyses. The first step (Model 1) included the control variables: age, education

and childhood socioeconomic status. In Model 2, three variables of interest were added: L2 AoA, L2 proficiency and language switching frequency. The statistical analyses were performed with SPSS version 25.

3 RESULTS

3.1 Descriptive data

Descriptive information on the three language groups' (monolinguals, early bilinguals and late bilinguals) background variables is presented in Table 4. The three language groups were compared on age, education, childhood socioeconomic status and gender. These comparisons revealed a significant main effect of age [$F(2,484) = 3.85$, $p < .05$]. Pairwise comparisons showed that the monolingual group was significantly older compared to the early bilingual group ($p < .01$), but the average age did not differ between the monolingual and the late bilingual group nor between the early and late bilinguals.

A main effect of education [$F(2,484) = 6.16$, $p < .01$] was also found. Pairwise comparisons revealed that the participants in the monolingual group had on average completed a significantly lower educational level ($p < .05$) compared with the early and late bilinguals. However, the early bilinguals and the late bilinguals did not differ significantly from each other on educational level. The group comparisons did not reveal any significant differences between the three language groups on gender [$\chi^2(4) = 3.23$, $p = .52$] or childhood socioeconomic status [$F(2,482) = .994$, $p = .37$].

To investigate the differences between early and late bilinguals on language proficiency, percentage of L2 use and language switching, independent samples t-tests were conducted. The results revealed that compared to the late bilinguals, the early bilinguals were more proficient in

their L2 ($t(263) = 6.94$, $p < .001$), used their L2 more frequently ($t(262) = 4.36$, $p < .001$), and switched between languages more frequently ($t(140) = 4.19$, $p < .001$). The results are summarized in Table 5.

Table 4

Means (Standard Deviations) of background variables and language use by language group

	Monolinguals	Early bilinguals (AoA ≤12 years)	Late Bilinguals (AoA >12 years)
n	220	115	150
Mean age (SD)	35.2 (11)	31.9 (10)	33.6 (10)
Gender	56.8% Female	56.5% Female	57.3% Female
Level of education			
Primary education	1.4%	0%	.7%
Lower secondary education	1.4%	.9%	.7%
Higher secondary education	26.4%	17.4%	18%
Basic vocational education	6.8%	2.6%	9.3%
Vocational university/other upper vocational education	15.9%	8.7%	14%
University: Bachelor´s/Master´s degree	46.4%	68.7%	52.7%
University: Doctoral degree	1.8%	1.7%	4.7%
Employment			
Employed	66.8%	65.2%	74.7%
Student	12.7%	28.7%	20.7%

Table 5
Means (Standard Deviations) of bilingualism-related features between two bilingual groups

	Early bilinguals (AoA ≤12 years)	Late bilinguals (AoA >12 years)
n	115	150
Mean L2 AoA (SD)	6 (4.4)	17.7 (6.2)
Mean L2 proficiency (SD)	3.48 (1.8)	2.2 (1.1)
L2 use in percentage (SD)	16.3 (20.4)	5.4 (8.1)
Language switching frequency (SD)	2 (1.2)	1.3 (.7)

A summary of the results of the WM performance measures by language group (monolinguals, early bilinguals, late bilinguals) are presented in Table 6. All scores have been z-transformed and then summed and averages calculated.

Table 6
*Means (Standard Deviations) of working memory performance by language group**

	Monolinguals	Early bilinguals (AoA ≤12 years)	Late bilinguals (AoA >12 years)
n	220	115	150
Mean verbal WM score (SD)	-.35 (3.01)	.43 (2.94)	.44 (2.87)
Mean visuospatial WM score (SD)	-.48 (2.98)	.51 (3.1)	.67 (2.96)
Mean n-back score (SD)	-.19 (1.73)	-.03 (1.72)	.48 (1.73)

**Positive values indicate better WM performance*

3.2 Visuospatial WM performance between the language groups

An ANCOVA was conducted to investigate differences in visuospatial WM tasks between the three language groups. The visuospatial WM composite was used as the dependent measure, and age and education served as covariates. Language group (monolingual, early bilingual and late bilingual) was used as the independent variable. The analysis revealed a significant main effect of language group ($F(2,480) = 5.79$, $p < .01$). Early and late bilinguals achieved significantly higher accuracy scores on the spatial WM tasks than monolinguals. Pairwise comparisons did not reveal any statistically significant differences between early and late bilinguals on visuospatial working memory tasks.

3.3 Verbal WM performance between the language groups

An ANCOVA was conducted to compare the three language groups on verbal working memory task performance. The verbal WM composite was used as the dependent variable and age and education as covariates. The language group (monolingual, early bilingual, late bilingual) was used as the independent variable. The results revealed a trend for a main effect of language group, with both early and late bilinguals achieving higher scores than monolinguals [$F(2,480) = 2.88$, $p = .057$]. Pairwise comparisons did not reveal any statistically significant differences between early and late bilinguals on verbal working memory tasks.

3.4 N-back performance between the language groups

An ANCOVA was performed with the n-back composite as the dependent variable, the language group (monolinguals, early bilinguals, late bilinguals) as the independent variable, and age and education as covariates. The results revealed a significant main effect of language group after controlling for age and education [$F(2,480) = 6.36$, $p < .01$], revealing an advantage of late bilinguals over monolinguals and early bilinguals.

The composite n-back score included both verbal and visuospatial n-back tasks. A separate analysis of each n-back task was also conducted given the findings on visuospatial and verbal WM. For both n-back tasks, pairwise comparisons revealed a significant effect of language group. In the verbal n-back task [$F(2,480) = 3.15$, $p = .044$] and in the visuospatial n-back task [$F(2,480) = 7.07$, $p < .01$]), the late bilinguals were significantly more accurate on the tasks than the monolinguals and early bilinguals.

Overall, these group comparisons suggest that bilingualism is associated with higher scores on WM tasks. However, the positive effect on the n-back task existed only for the late bilinguals. This prompted an exploration of the particular aspects of bilingual experience and their links to WM in separate multiple regression analyses.

3.5 Hierarchical multiple regression analyses of WM performance

A summary of the results of the hierarchical multiple regression analyses (Models 1 and 2) are presented in Table 7. For the purpose of these analyses, the bilingual groups were treated as one group (no separation was made between early and late bilinguals) and L2 age of acquisition was used as a continuous variable. Model 1 included background variables: age, education, and childhood socioeconomic status (SES). In Model 2, three key features of bilingual experience were added: L2 AoA, L2 proficiency and language switching frequency. In the second model, language switching frequency was used as a feature of bilingual experience instead of percentage of language use, due to the shared variance between the two. Out of these two variables, language switching frequency was considered as the relevant one concerning the BEA hypothesis (e.g., Linck, Schwieter & Sunderman, 2012). The second model was compared to the first model which was the null model in the comparison.

Multicollinearity was tested for the Model 1 predictors (Age, Tolerance = .963, VIF =1.038; Education, Tolerance = .956, VIF = 1.046; Childhood SES, Tolerance = .993, VIF = 1.007) and for the Model 2 predictors (Age, Tolerance = .942, VIF = 1.062; Education, Tolerance = .924, VIF = 1.082; Childhood SES, Tolerance = 0.959, VIF = 1.043; L2 AoA, Tolerance = .815, VIF = 1.226; L2 proficiency, Tolerance = .672, VIF = 1.488; Language switching frequency, Tolerance = .745, VIF = 1.343) and it was not a concern for the models.

For the verbal, visuospatial and n-back WM composites, none of the models were significant. There were no effects of either background variables or the bilingualism-related variables. For the verbal WM composite, Model 1 was not significant (adjusted R^2 = -.007, F (3,261) = .356, p = .785) and Model 2 was not significant either (adjusted R^2 = -.012, F (3,258) = .617, p = .604). The negative adjusted R^2 values for these two models indicate a particularly poor goodness-of-fit. For the visuospatial WM Model 1 was not significant (adjusted R^2 = .013, F (3,261) = 2.157, p = .094) and neither was Model 2 (adjusted R^2 = .002, F (3,258) = .031 p = .993). For n-back Model 1 was not significant (adjusted R^2 = .015, F (3,261) = 2.314, p = .076) and Model 2 was not significant either (adjusted R^2 = .025, F (3,258) = 1.91, p = .13). While both of the models predicting n-back were non-significant and thus not calling for further scrutiny, it can nevertheless be noted that they indicated a negative association between age and n-back performance (Model 1: β = -.14, p = .01; Model 2: β = -.14, p = .01). The hierarchical multiple regression analysis concerning n-back was also conducted for late bilinguals only because of the significant group differences in performance between late bilinguals and the other language groups. Model 1 was not significant (adjusted R^2 = .005, F(3,146) = 1.275, p = .285) and neither was Model 2 (adjusted R^2 = 0, F(6,143) = .979, p = .44).

Table 7.

Hierarchical multiple regression models for background and language predictors of WM performance in the bilingual participants (n=265).

A. Predictors of verbal WM performance.

	Model 1			Model 2		
Variable	**B**	**SE B**	**β**	**B**	**SE B**	**β**
Age	.016	.018	.056	.016	.018	.057
Education	.039	.145	.017	.015	.147	.006
Childhood SES	-.042	.147	-.018	-.35	.150	-.015
L2 AoA				.017	.025	.046
L2 proficiency				.053	.138	.029
Language switching				.290	.295	.070
Adjusted R^2		-.007			-.012	
F for change in R^2		.356			.617	

*p<.01.

B. Predictors of visuospatial WM performance.

	Model 1			Model 2		
Variable	**B**	**SE B**	**β**	**B**	**SE B**	**β**
Age	-.04	.019	-.14	-.04	.019	-.13
Education	.13	.15	.05	.12	.15	.052
Childhood SES	.17	.15	.07	.17	.15	.07
L2 AoA				.00	.026	-.001
L2 proficiency				.027	.14	.014
Language switching				.03	.31	.008
Adjusted R^2		.013			.002	
F for change in R^2		2.16			.031	

*p<.01.

C. Predictors of n-back performance.

	Model 1			Model 2		
Variable	**B**	**SE B**	**β**	**B**	**SE B**	**β**
Age	-.02	.01	-.14*	-.03	.01	-.16*
Education	-.08	.09	-.06	-.05	.09	-.04
Childhood SES	.04	.09	.03	.03	.09	.02
L2 AoA				.01	.01	.06
L2 proficiency				-.07	.08	-.06
Language switching				-.16	.17	-.06
Adjusted R^2		.015			.025	
F for change in R^2		2.31			1.91	

*p<.01.

4 DISCUSSION

Over the recent years, the commonly held bilingual executive advantage (BEA) hypothesis has been challenged with meta-analyses revealing insignificant or non-existent performance differences between bilinguals and monolinguals (see Lehtonen et al., 2018). Thus, the topic is still highly debated, and the present study sought to clarify the relationships between bilingualism and one executive function domain, namely working memory. At the same time, the present study addressed some of the methodological issues that have affected previous research. Instead of analysing individual tasks, the present study employed WM composite measures (verbal WM, visuospatial WM, n-back) based on the latent structure of the current tasks (derived from Waris et al., 2017) that should provide a better reliability. Furthermore, the current sample was larger and more heterogeneous than in many previous studies, and several potentially important background variables were taken into account.

The present group comparisons between monolinguals, early bilinguals, and late bilinguals revealed that bilinguals outperformed monolinguals on n-back, visuospatial WM tasks and on verbal WM tasks. For the n-back tasks, the late bilingual group performed better than the monolingual group, but there was no significant difference between the performance of early bilinguals and monolinguals. For the visuospatial WM and the verbal WM, both bilingual groups outperformed the monolingual group, but there was no statistically significant difference between the early and late bilinguals. However, the multiple regression analyses within the bilingual participants revealed no effects of either the background variables or the language-related variables on the verbal, visuospatial or n-back WM composites. Therefore, the models did not significantly address the variation in the WM performance on the three composites.

4.1 Is there a difference between bilinguals and monolinguals on working memory performance?

The group comparisons in this study show a statistically significant positive association between bilingualism and WM performance. These results are broadly in line with previous meta-analyses that show a positive, but weak association between bilingual experience and WM performance (Adesope et al., 2010; Grundy & Timmer, 2016; Von Bastian et al., 2017) and inhibitory control (Donnelly, 2016), as well as attention (Adesope et al., 2010). However, in the recent meta-analysis by Lehtonen and colleagues (2018), these effects disappeared when correcting for publication bias. In addition, the closely related study by Lukasik and colleagues (2018) employed a genetic matching procedure on the same data due to the significant differences between groups in background variables (i.e. age and education) to ensure equal distribution of covariates. After using the genetic matching procedure, the analyses revealed similar results, with the exception that the group comparisons between monolinguals, early bilinguals and late bilinguals were no longer statistically significant for the verbal WM composite. This would indicate that despite of the covariance analysis used here, the group differences on the verbal composite were likely caused by the differences in background variables between bilinguals and monolinguals and not by the bilingual experience itself. Lukasik and colleagues (2018) also conducted a Bayesian ANCOVA to investigate the statistically significant differences between the language groups on the three WM composites. The Bayes factors only provided evidence for group differences on the n-back task and evidence for the absence of a group difference on the verbal WM composite. Additionally, no evidence of a group difference or a lack thereof on the visuospatial WM composite was provided, calling into questions the positive effects in this study. On the n-back composite, the late bilinguals received

a higher score compared to the monolingual and the early bilingual group which were comparable to each other, and these findings were similar even after the genetic matching procedure (see Lukasik, 2018).

The multiple hierarchical regression analyses in the present study were conducted to follow up the group differences and to examine if key characteristics of the bilingual experience (L2 AoA, L2 proficiency, language switching frequency) together with the background variables would predict WM performance. The results were not significant for the regression models on the verbal, the visuospatial or the n-back WM composites. The low (partly even negative) adjusted R-squared values in the hierarchical multiple regression analyses on the three WM composites indicates poor fit for the models in explaining the variation of the WM performance. All in all, these results indicate that either the bilingual experience was not measured adequately, or that the observed group differences on WM performance were mediated by some uncontrolled factors. The second alternative would also be in line with the results in the study by Lukasik et al. (2018).

One could also question if the background questionnaire used was able to capture all essential features of the bilingual experience. Measuring bilingualism is challenging as it is not a categorical variable (e.g., Bialystok, 2017). The Adaptive Control hypothesis presented by Green and Abutalebi (2013) suggests that the interactional context that the bilingual is immersed in affects the cognitive load. A dual-language context where the bilingual has to switch between languages depending on the speaker places more cognitive load as compared to single-language contexts, and would thus lead to training effects. For future studies, there is thus reason to further investigate if different language use patterns in different interactional contexts are associated with different EF gains (Green & Abutalebi, 2013).

The studies by Green and Abutalebi (2013), Jylkkä and colleagues (2017) and many more (e.g. Soveri, Rodríguez-Fornells, & Laine, 2011) have used the within-group correlational study design to investigate the associations between language switching and cognitive advantages. However, this design could be used more broadly as a complement to the natural groups design which is not considered to be the best design to capture BEA (e.g. Laine & Lehtonen, 2018), as executive functions could be affected by many different factors. For example, the study by Von Bastian, Souza and Gade (2015) did not compare bilinguals to monolinguals, but instead investigated how different aspects of the bilingual experience influence EF within a group of bilinguals. The bilingualism-related features analyzed in their study were AoA, proportion of language use and L1/L2 language proficiency as continuous bilingualism-related predictors of nine components of EF measured with several tasks. In addition, factors such as SES, video-gaming, physical training and musical training were controlled for. The analyses revealed that none of the examined features of bilingual experience (i.e. AoA, proportion of language use and L1/L2 language proficiency) significantly predicted measures of inhibitory control, monitoring, switching, or general cognitive performance.

4.2 Causality of the relationship between WM and bilingual experience

As was already noted, the present study is a cross-sectional correlational experiment, and one cannot draw conclusions on the causality of the relationships between WM capacity and bilingualism on the basis of these data. Therefore, the findings of this study could also be explained by individual differences or uncontrolled variables. Even though practice in using two languages could lead to enhanced WM capacity, individuals with higher WM capacity could also have better abilities to master a L2 (Michael & Gollan, 2005). Previous studies suggest that WM capacity and nonverbal intelligence are strong predictors of L2 learning in adults (Brooks &

Kempe, 2013). The present results could also be explained by the late bilinguals (who performed better in the n-back tasks) having higher executive skills to begin with which would have provided them a better aptitude to L2 learning. In line with this, executive skills would instead be the cause for, rather than a consequence of late bilingualism, at least in part of that group. Similarly, the meta-analysis by Linck and colleagues (2014) revealed a positive association between WM and L2 processing and proficiency outcomes. On the other hand, Paap (2019) has suggested that when bilinguals learn their L2 later in life, they might undergo a phase of more intensive use of their executive skills when the L2 is not yet fully automated. This could also provide a potential explanation for the results in the study. However, as previously discussed, even though many of the studies on the bilingual advantage report better EF task performance for bilinguals compared with monolinguals, individual studies show considerable heterogeneity, and many authors have now provided alternative explanations for these effects, emphasizing their weakness and speculating that they may be limited to special circumstances (Hilchey et al., 2015; Paap et al., 2014; 2015; 2016).

4.3 Limitations and strengths of the study

The present study has both limitations and strengths that should be addressed. First, a subjective self-report was used to collect information about the participants´ language background, including questions about language proficiency and language switching. It can be difficult for the participants to accurately estimate their skill level or the frequency of their daily language switching, and this could affect the accuracy of these measures. In addition, it would have been beneficial to include questions about the interactional contexts where the bilinguals used their two languages, as that may affect the cognitive load (Green & Abutalebi, 2013) and thereby the putative training effect. However, it is difficult to comprehensively measure the bilingual

experience, as it shows a high variability both between and within bilingual individuals. This is a major challenge for all studies on the BEA.

Another line of criticism against BEA studies is that confounding variables such as culture (Yang, Yang & Lust, 2011), education and socioeconomic status (Evans & Shamberg, 2009; Hackmann & Farah, 2009), immigration status (de Bruin, Bak & Della Sala, 2015), video gaming (e.g. Hutchinson et al., 2016) and music training (e.g. Moreno et al., 2011) are likely to affect measures of EF and should therefore be controlled for. This is also a limitation in the present study, as a natural groups design was used and controlling for all potential confounding factors cannot be done. In addition, the language groups were not properly matched on all background variables. It should also be acknowledged that the participants completed the WM test battery online without any direct control from test leaders, which could increase error variance in task performance.

Additionally, there are some limitations regarding the representativeness of the adult sample included in the study. Lukasik and colleagues (2019) used the same sample in another study, and found that the current sample does not represent the entire U.S. population on various background variables. According to their findings, the people in this sample were younger, more educated, and had a lower rate of employment. Additionally, females, Caucasians and Asians were overrepresented while Hispanic and Black Americans were underrepresented when comparing to the overall U.S. population.

On the other hand, the key strength of this study compared to previous relevant research is the large sample size of 485 adult participants. Many of the previous studies on the bilingual advantage in the WM domain have used simple span tasks to measure WM capacity. The simple span task is considered to demand WM storage rather than WM processing (Scharinger et al.,

2017), whilst complex span tasks employed here tap both WM maintenance and manipulation (Conway et al., 2005). Moreover, updating, attention control and other higher-order WM processes were measured here by running memory and n-back tasks (Owen et al., 2005). Also, composite measures based on latent structure of the test battery (adopted from Waris et al., 2017) were used as WM measures to ensure better reliability.

4.4 Conclusions and aims for future research

To sum up, the results in this study reveal some group differences on WM favouring bilinguals when compared with monolinguals, but together with the non-significant regression analyses within the bilingual participants, the findings do not offer any clear or consistent support for the BEA hypothesis in the working memory domain. Thus, the relationship between WM task performance and bilingualism remains unclear, and we do not know what in the bilingual experience could drive such effects. The present study was conducted with an adult sample and does not make any attempt to explain bilingual advantages in children which according to some researchers could be more prominent (Hilchey et al., 2015).

This study highlights the need for more precise and consistent ways of measuring bilingual experience and defining bilingualism in future research, as has been discussed in previous studies (Paap, Johnson & Sawi, 2016). Self-reported language switching and proficiency has also been considered as problematic (e.g. Grundy & Timmer, 2017), calling for more objective and coherent measures in this field of research.

In future research, it would be of interest to identify the specific type of, or the combination of bilingual experience that might drive cognitive benefits. This would entail studies investigating the differences between bilingual groups to find the critical experience and circumstances that affect EF. In line with the Adaptive Control hypothesis by Green and

Abutalebi (2013) future studies could investigate what kind of effects different patterns of language use could have on cognition, as this could be a viable explanation for some of the differences between bilingual groups (Green & Abutalebi, 2013). In addition, the language groups should be matched on broad background variables and include tasks that demonstrate high convergent validity, and the sample sizes should be adequate for a desired power of a study. As acquisition of a second language is a complex process, it would be beneficial to the BEA debate to conduct longitudinal studies that examine the relationships between foreign language learning and cognitive control in order to better understand the cognitive consequences of bilingualism (Takahesu Tabor, Mech & Atagi, 2018).

5 Swedish summary – Svensk sammanfattning

Skillnaden i arbetsminnesprestationer mellan tvåspråkiga och enspråkiga vuxna

Inledning

Under det tidiga 1900-talet trodde man att tvåspråkighet leder till kognitiva svårigheter (t.ex. Smith, 1923), men efter vissa metodologiska förbättringar i forskningen påvisades sedermera att tvåspråkighet tvärtom kunde leda till förbättringar i den exekutiva förmågan (Peal & Lambert, 1962). De exekutiva fördelarna eller det exekutiva försprånget hos tvåspråkiga är numera ett debatterat ämne inom forskningsfältet, eftersom forskningsresultaten är motstridiga.

Tidiga studier som jämförde tvåspråkiga med enspråkiga målade upp en sammanhängande representation av det exekutiva försprånget hos tvåspråkiga (EFT), eftersom tvåspråkiga presterade bättre än enspråkiga på uppgifter som kräver inhibition av irrelevant information (Bialystok & Martin, 2004; Bialystok m.fl., 2004, 2008; Carlson & Meltzoff, 2008; Costa, Hernández & Sebastián-Gallés, 2008; Bialystok & Viswanathan, 2009, Soveri, Rodriguez-Fornells & Laine, 2011), och även på uppgifter som kräver kognitiv kontroll (Bialystok & Viswanathan; Costa et al., 2009) och lagring av information i arbetsminnet (Bialystok m.fl., 2004). Denna fördel i den exekutiva förmågan har ansetts utvecklas som en följd av att tvåspråkiga utsätts för naturlig träning av de exekutiva färdigheterna genom att de tvingas byta mellan två eller flera språk och inhibera det språk som för tillfället inte är i användning. Språkbyte antas förbättra uppmärksamhetsväxlingen, monitoreringen, men även inhiberingen då den tvåspråkiga personen försöker undvika störningar från det språk som inte används just då (Linck, Schwieter & Sunderman, 2012). Fynd i neuroavbildningsstudier tyder på att den språkliga kontroll som tvåspråkiga förmodas utöva involverar samma områden som då man utför uppgifter som kräver exekutiva funktioner. Dessa regioner är anterior cingulate cortex

och dorsolateral prefrontal cortex (Abutalebi m.fl., 2007; Abutalebi & Green, 2008; Van Heuven m.fl., 2008; Abutalebi m.fl., 2012; Luk m.fl., 2012). Även om dessa fynd tyder på att språkbyte och exekutiva funktioner engagerar samma neuroanatomiska områden, betyder det ändå inte att samma funktioner skulle vara inblandade (Paap, 2014).

De kognitiva fördelarna som tvåspråkighet antas medföra har vanligtvis undersökts genom att jämföra tvåspråkiga med enspråkiga i test som mäter exekutiva färdigheter, men alternativa metodologiska närmandesätt kunde också vara möjliga. Man kunde exempelvis undersöka sambandet mellan olika områden inom den tvåspråkiga upplevelsen och arbetsminnesprestationer för att öka förståelsen kring vilka särdrag inom tvåspråkighet som kan medföra kognitiva fördelar. Tidigare studier tyder till exempel på att det kan finnas ett samband mellan språkkunskapsnivå och arbetsminnesprestationer (t.ex. Blom m.fl., 2014), och även om teorier om språkbyte antar att en ökning i språkbytesfrekvens kunde leda till bättre kognitiva färdigheter över tid, uppvisar en del studier inget sådant samband (t.ex. Jylkkä m.fl., 2017; Soveri m.fl., 2011).

Exekutiva funktioner och arbetsminne är koncept som står i relation till varandra och således antas tvåspråkiga enligt EFT-hypotesen även prestera bättre än enspråkiga på arbetsminnestest (e.g. Engle, 2002; Miyake & Friedman, 2012). Arbetsminnet är ett tillfälligt lagringssystem med begränsad kapacitet som gör det möjligt att medvetandehålla och manipulera information under en kortare tidsperiod (Conway m.fl., 2007). Dessutom innehar arbetsminnet en central roll i pågående kognitiva processer så som slutledning, förståelse, problemlösning och inlärning (Cowan, 2010; Cowan, 2014). Arbetsminnet har även antagits ha en funktion vid språkinlärning och -förståelse, eftersom exekutiv kontroll krävs framförallt för bearbetning av ett språk då individen ännu inte är flytande i det (i.e. det andra språket). Detta tyder också på att

arbetsminnet spelar en roll vid bearbetningen av det andra språket och utvecklandet av individens språkkunskaper (Linck, Osthus, Koeth & Bunting, 2014). Av den anledningen är den kausala riktningen på förhållandet mellan arbetsminneskapacitet och tvåspråkighet fortfarande tvetydig (Linck m.fl., 2014).

Inom forskningsfältet har sammanlagt åtta metaanalyser undersökt skillnader i exekutiva färdigheter mellan tvåspråkiga och enspråkiga barn och vuxna (Adesope m.fl., 2010; Linck m.fl., 2014; De Bruin m.fl., 2015; Donnelly, 2016; Grundy & Timmer, 2017; Von Bastian et al., 2017; Lehtonen m.fl., 2018; Donnelly m.fl., 2019). I test som mäter exekutiva färdigheter visar fem av metaanlyserna små, men signifikanta prestationsskillnader till fördel för tvåspråkiga individer (Adesope m.fl., 2010; de Bruin m.fl., 2015; Donnelly, 2016; Grundy & Timmer, 2017; Von Bastian m.fl., 2017), medan resultaten i de senare metaanalyserna inte uppvisar signifikanta skillnader mellan tvåspråkiga och enspråkiga (Lehtonen m.fl., 2018; Donnelly m.fl., 2019).

De blandade resultaten inom forskningsfältet har fått en del forskare att ifrågasätta EFT-hypotesen och studiernas metodologiska kvalitet (e.g. Paap & Sawi, 2014; Duñabeitia & Carreiras, 2015; Calvo m.fl., 2016; Paap m.fl., 2017). Kritik har bland annat riktats mot studier med små sampel, eftersom små sampelstorlekar kan försvaga studiens statistiska kraft (Asendorpf m.fl., 2013), liksom även mot användningen av en naturlig gruppdesign som kunde medföra okontrollerade variabler som intelligens, kultur (Yang, Yang & Lust, 2011), utbildning (Evans & Shamberg, 2009), immigrantstatus (de Bruin, Bak, & Della Sala, 2015), socioekonomisk ställning (Hackmann & Farah, 2009), videospelande (t.ex. Bediou mfl., 2018) eller musikalisk träning (t.ex. Moreno m.fl., 2011), vilka kunde påverka EF. Därtill har testen som mäter exekutiva funktioner kritiserats p.g.a. brist på konvergent validitet eftersom flera studier uppvisat svaga korrelationer mellan mätinstrumenten (bl.a. Miyake et al., 2000; Paap &

Greenberg, 2013; Paap & Sawi, 2014; Waris m.fl., 2017). Därtill har det hävdats att det förekommer publiceringsbias inom forskningsfältet och det finns studier som antyder att de studier som stöder EFT-hypotesen med större sannolikhet publiceras än sådana som förkastar hypotesen (Bakker, 2015; Gathercole, 2015; de Bruin & Della Sala, 2015).

För att ytterligare undersöka sambandet mellan tvåspråkighet och arbetsminneskapacitet undersökte den föreliggande studien skillnaden i arbetsprestationer mellan tvåspråkiga och enspråkiga vuxna. I studien inkluderades ett stort heterogent sampel och summavariabler användes vid bedömningen av arbetsminnet, vilket i en positiv bemärkelse skiljer denna studie från tidigare forskning.

Syfte

Syftet med denna föreliggande studie var att undersöka skillnaden i arbetsminnesprestationer mellan tvåspråkiga och enspråkiga vuxna på tre summavariabler: verbalt arbetsminne, visuospatialt arbetsminne och n-back. De sammansatta arbetsminnesmåtten baserades på den latenta strukturen av samma data (Waris m.fl., 2017). Tre centrala faktorer relaterade till tvåspråkighet inkluderades i analysen: självrapporterad ålder vid förvärv av det andra språket, kunskapsnivå i det andra språket och språkbytesfrekvens. De tre faktorerna valdes utifrån teorier som ligger som grund för EFT-hypotesen, exempelvis kan åldern vid förvärv av det andra språket indikera hur länge man tränat sina EF på ett naturligt sätt genom att byta språk eller inhibera de språk som inte är i användning, vilket kan ha en inverkan på den kognitiva förmågan (Luk, de Sa & Bialystok, 2011).

I denna studie har de metodologiska utmaningarna från tidigare studier inom ämnet undvikits genom att man rekryterat ett mångsidigt och stort sampel som indelats i tre

språkgrupper (enspråkiga, tidiga tvåspråkiga, sena tvåspråkiga) och genom användning av ett mångsidigt arbetsminnestestbatteri bestående av summavariabler för att mäta arbetsminneskapacitet och uppdatering. På basis av tidigare forskning utarbetades och undersöktes följande forskningsfrågor:

- **Fråga 1:** Finns det en statistiskt signifikant skillnad i arbetsminnesprestationer mellan den tvåspråkiga och den enspråkiga gruppen?
- **Fråga 2:** Finns det en statistiskt signifikant skillnad i arbetsminneskapacitet och uppdatering mellan den tidiga och den sena tvåspråkiga gruppen?
- **Fråga 3:** Är måtten på de variabler som tvåspråkig erfarenhet omfattar relaterade till arbetsminnesprestationer bland tvåspråkiga?

Metod

Beskrivningen nedan och materialet i den föreliggande studien baserar sig på en studie av Waris jämte kollegor (2017) där samma data analyserades med fokus på den latenta strukturen på arbetsminnesmått. Läsaren hänvisas till Waris jämte kollegors artikel (2017) för närmare information. För att rekrytera deltagare till studien utnyttjades en crowdsourcing-plattform Amazon Mechanical Turk. Sammanlagt slutförde 711 deltagare studien, varav 226 personer exkluderades på grund av att de t.ex. hade använt sig av externa hjälpmedel, de uppvisade höga poäng på depressivitetsformulär, rapporterade engelska eller meningslösa alternativ som sitt andra språk m.fl. Sammanlagt bestod samplet efter exkluderingarna av 485 deltagare varav 265 var tvåspråkiga. I den tvåspråkiga gruppen var spanska (141 deltagare), franska (41 deltagare)

och tyska (20 deltagare) de vanligaste språken som deltagarna uppgav sig tala utöver sitt modersmål engelska.

Studien bestod av ett frågeformulär och tio separata arbetsminnestest. De tio testen omfattade fyra uppgiftsparadigm: enkelt minnesspann (en framåtversion och bakåtversion), komplext minnesspann, fortlöpande minnesspann och n-back. Paradigmen omfattade både en numerisk-verbal och en visuospatial version som påminde om varandra. Frågeformuläret däremot bestod av frågor om språkbakgrund och -beteende där deltagarna skulle rapportera vilka språk de kunde, när de lärt sig språken, nivån på språkfärdigheterna (1 – nybörjarnivå till 6 – modersmålsnivå). Därtill fick deltagarna utvärdera sitt språkbruk under de senaste två åren och analysera sitt språkbytesbeteende. Deltagarna delades de in i två grupper på basis av när de lärt sig sitt andra språk: Tidiga tvåspråkiga (som lärt sig sitt andra språk innan de hade fyllt 12 år) och sena tvåspråkiga (som lärt sig sitt andra språk efter att de fyllt 12 år).

För att analysera skillnaden i arbetsminnesprestationer mellan den tvåspråkiga och den enspråkiga gruppen utfördes ANCOVA separat för de tre summavariablerna (verbalt AM, visuospatialt AM, n-back) med ålder och utbildning som kovariat. Därtill utfördes ANOVA för att analysera skillnaderna i arbetsminnesprestationer inom den tvåspråkiga gruppen, d.v.s. mellan tidiga och sena tvåspråkiga. Därefter genomfördes ännu en hierarkisk multipel regressionsanalys för hela samplet med de tre summavariablerna som beroende variabler. I den första modellen användes ålder, utbildning och socioekonomisk ställning i barndomen som kontrollvariabler. I den andra modellen utgjorde kontrollvariablerna förvärv av det andra språket, språkkunskaperna i det andra språket och språkbytesfrekvensen.

Resultat

Analyserna synliggjorde en statistiskt signifikant skillnad mellan språkgrupperna, där den tvåspråkiga gruppen presterade bättre än den enspråkiga gruppen på visuospatiala arbetsminnestest [F (2,480) = 5,79, p < .01]. Inga statistiskt signifikanta skillnader kunde påvisas mellan den tidiga och den sena tvåspråkiga gruppen. Därtill påvisades en statistisk signifikant skillnad mellan språkgrupperna [F (2,480) = 2,88, p = .057] där den tvåspråkiga gruppen presterade bättre än den enspråkiga gruppen på verbala arbetsminnestest. Däremot kunde inga statistiskt signifikanta skillnader påvisas mellan den tidiga och den sena tvåspråkiga gruppen.

En signifikant skillnad i arbetsminnesprestation efter kontroll av ålder och utbildning kunde även påvisas i n-back där den sena tvåspråkiga gruppen presterade bättre än den enspråkiga och den tidiga tvåspråkiga gruppen [F (2,480) = 6,36, p < .01]. Skillnaden kunde påvisas gälla för både den verbala versionen på n-back [F (2,480) = 3,15, p = .044] och för den visuospatiala på n-back [F (2,480) = 7,07, p < .01].

Hierarkiska regressionsanalyser visade inga signifikanta samband mellan bakgrunds- eller språkvariablerna för verbala AM, visuospatiala AM eller n-back. Hierarkiska regressionsanalyser utfördes också enbart med den sena tvåspråkiga gruppen p.g.a. de gruppskillnader som påvisades för n-back, men ingen av regressionsmodellerna visade sig vara statistiskt signifikant.

Diskussion

Resultaten i den föreliggande studien indikerar att tvåspråkiga som grupp kan uppvisa bättre arbetsminnesprestationer än enspråkiga. Det här gällde speciellt tvåspråkiga som lärt sig det andra språket senare i livet. Dessa resultat ligger i linje med tidigare meta-analyser som även de framhävt positiva samband mellan tvåspråkighet och kognitiv förmåga (Adesope m.fl., 2010; Grundy & Timmer, 2016; Von Bastian m.fl., 2017), inhibitorisk kontroll (Donnelly, 2016) och uppmärksamhet (Adesope m.fl., 2010). I en av de senare meta-analyserna (Lehtonen, 2018) försvann dock dessa effekter efter att man korrigerat för publiceringsbias.

Gruppjämförelserna i den föreliggande studien visar att tvåspråkiga presterade bättre än enspråkiga i n-back, visuospatialt AM och verbalt AM. Den sena tvåspråkiga gruppen presterade bättre än den enspråkiga gruppen i n-back, men ingen signifikant skillnad i prestationer kunde påvisas mellan den tidiga tvåspråkiga och den enspråkiga gruppen. För visuspatialt AM och verbalt AM presterade de tvåspråkiga grupperna bättre än den enspråkiga gruppen, men inga skillnader kunde påvisas mellan den sena och den tidiga tvåspråkiga gruppen gällande prestationerna. I regressionsanalyserna påvisade inga signifikanta samband mellan bakgrundsvariablerna eller de språkrelaterade variablerna på verbalt AM, visuospatialt AM och n-back.

I en studie av Lukasik jämte kollegor (2018) där samma data utnyttjades utfördes även en genetisk matchningsprocedur mellan grupperna p.g.a. skillnader i bakgrundsvariabler, mer specifikt ålder och utbildningsbakgrund. Då samma analyser utfördes efter den genetiska matchningen var skillnaderna mellan grupperna på de verbala arbetsminnestesten inte längre signifikanta. Därtill visade deras Bayesiska ANCOVA att skillnaderna mellan grupperna varken fick stöd eller kunde förkastas utifrån de visuospatiala arbetsminnestesten. Således kan

gruppskillnaderna på verbalt AM och visuospatialt AM även ifrågasättas i den föreliggande studien, och ska tolkas med försiktighet.

Eftersom de hierarkiska regressionsanalyserna inte visade signifikanta samband mellan bakgrunds- och tvåspråkighetsvariabler och arbetsminnesprestationer på de tre summavariablerna kunde man ifrågasätta ifall gruppskillnaderna egentligen berodde på skillnader i okontrollerade variabler eller på att frågeformuläret inte lyckats fånga upp tvåspråkighet i sin helhet. Tvåspråkighet är överlag svårt att mäta och bl.a. Green och Abutalebi (2013) menar att den omgivning som den tvåspråkiga befinner sig i är av betydelse. Ju mer den tvåspråkiga tvingas avsiktligt att byta språk inom en och samma kontext, desto intensivare kontroll krävs. Således har olika språkbeteenden olika påverkan på kognitionen och därför kunde man i den föreliggande studien noggrannare ha undersökt de olika formerna av språkanvändning och språkbeteende för att utreda vilka specifika delar av tvåspråkighet som leder till kognitiva fördelar.

Studien i fråga har även en del metodologiska begränsningar som bör behandlas. Språkkunskaper och –vanor undersöktes i studien genom självskattning och eftersom det kan vara svårt att själv utvärdera sina kunskaper och sin språkanvändning kan detta ha påverkat måttens tillförlitlighet. Därtill utfördes arbetsminnestesten i en okontrollerad miljö, vilket även kan ha påverkat resultatens tillförlitlighet. Det måste även framhävas att en av de största metodologiska bristerna i studien var skillnaderna mellan grupperna i bakgrundsvariabler, mer specifikt skillnader i ålder och utbildningsgrad, men även andra okontrollerade variabler kunde ha påverkat resultaten. Slutligen kan det påpekas att studien är en tvärsnittsstudie, vilket innebär att antaganden om kausalitet inte kan få stöd utifrån den studiedesign som använts.

Sammanfattningsvis, indikerar resultaten i den föreliggande studien att tvåspråkiga kan uppvisa bättre arbetsminnesprestationer än enspråkiga. Detta gällde speciellt tvåspråkiga som lärt sig det andra språket senare i livet. Samtidigt finns det orsak att anta att de här skillnaderna uppstått som resultat av okontrollerade bakgrundsvariabler, eftersom väsentliga drag av tvåspråkighet såsom åldern då man lärt sig det andra språket inte predicerade arbetsminnesprestationer inom tvåspråkiga. Tidigare forskning om de kognitiva fördelarna hos tvåspråkiga har avslöjat motstridiga resultat och därav är debatten om det exekutiva försprånget hos tvåspråkiga (EFT) fortfarande pågående. Den här studien ger inte heller stöd för EFT-hypotesen. Oavsett om koncensus om de kognitiva fördelarna av tvåspråkighet inte ännu uppnåtts medför tvåspråkighet onekligen flera andra fördelar. Framtida forskning kring EFT-hypotesen kunde försöka identifiera den specifika typen av eller kombinationen av erfarenheter som kan medföra kognitiva fördelar. Det vore även av intresse att utföra longitudinella studier där relationen mellan språkbearbetning och kognitiv kontroll framgår, för att skapa bättre förståelse av tvåspråkighetens kognitiva konsekvenser (Takahesu Tabor, Mech & Atagi, 2018).

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Stella Ritamäki

PRESSMEDDELANDE

Skillnader i arbetsminnesprestationer mellan tvåspråkiga och enspråkiga – men beror dessa skillnader på tvåspråkighet?

Pro gradu-avhandling i psykologi
Fakulteten för humaniora, psykologi och teologi, Åbo Akademi

Resultaten från en studie utfört vid Åbo Akademi indikerar att tvåspråkiga som grupp kan uppvisa bättre arbetsminnesprestationer än enspråkiga. Detta gällde speciellt tvåspråkiga som lärt sig det andra språket senare i livet. Samtidigt finns det orsak att anta att de här skillnaderna uppstått som resultat av okontrollerade bakgrundsvariabler, eftersom väsentliga drag av tvåspråkighet såsom åldern då man lärt sig det andra språket predicerade inte arbetsminnesprestationer inom tvåspråkiga.

Tidigare forskning om de kognitiva fördelarna hos tvåspråkiga har avslöjat motstridiga resultat och därav är debatten om det exekutiva försprånget hos tvåspråkiga (EFT) fortfarande pågående. Den här studien ger inte heller stöd för EFT-hypotesen. Oavsett om koncensus om de kognitiva fördelarna av tvåspråkighet inte ännu uppnåtts medför tvåspråkighet onekligen flera andra fördelar.

I studien deltog sammanlagt 485 vuxna och data till studien samlades in genom tio arbetsminnestest samt genom att deltagarna fyllde i ett frågeformulär med frågor om språkkunskaper och språkanvändning.

Avhandlingen utfördes av Stella Ritamäki under handledning av Matti Laine och Karolina Lukasik.

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