Emergent Bilingualism and Working Memory Development in School Aged Children

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Author note

Abstract

The present research explores working memory (WM) development in monolingual as well as emergent bilingual children immersed in an L2 at school. Evidence from recent years suggests that bilingualism may boost domain-general executive control, but impair non-executive linguistic processing. Both are relevant for verbal WM, but different paradigms currently in use vary in the degree to which they reflect these sub-processes. We found that only younger immersion students outperformed monolinguals on the n-back task, a measure of executive WM updating, but showed a relative deficit in L1 rapid naming, and to a lesser degree, reading span scores. Age effects suggest that rather than ultimate performance levels, bilingualism alters the developmental course of WMprocesses. We conclude that emergent bilingualism may modulate WM development in school-aged children at the sub-component level, but detecting this modulation is contingent on task selection.

Bilingualism is among the factors that can affect cognitive development, slowing or accelerating the acquisition and maturation of particular cognitive skills. While certain lags or deficits have been observed in the realm of language development and linguistic processing, the development of executive functions may benefit from multiple language competence and use (for a review, see Bialystok, 2009). Until recently, research on the cognitive consequences of bilingualism had been based almost exclusively on highly proficient and relatively balanced bilinguals who had acquired both languages early in life (before starting school) at home or in the community (see Adesope, Lavin, Thompson & Ungerleider, 2010, Bialystok, 2009, Hilchey & Klein, 2011). Recent research, however, suggests that if the immersion duration has been sufficient, the beneficial effect bilingualism has on executive control may extend to second language learners attending bilingual immersion schools (Nicolay & Poncelet, 2013, 2015). Immersion schooling, where the foreign language is not just the subject, but the medium of instruction, provides children from monolingual homes and communities with the opportunity for a bilingual education and is thus becoming increasingly popular. In what way this "path" to bilingualism affects the development of cognitive skills and abilities is therefore of critical importance. Here we aim to explore the development of working memory (WM) through school age in monolingual children and children who are in the process of becoming bilingual via attendance of an immersion school.

WM is key to the development of complex cognitive skills such as mathematics (Raghubar, Barnes & Hecht, 2010) and reading comprehension (Carretti, Borella, Cornoldi & de Beni, 2009), and is a predictor for academic attainment (Gathercole, Pickering, Knight & Stegmann, 2004). It is thus unsurprising that researchers have started to explore the consequences of bilingualism on WM development (e.g., Engel de

Abreu, 2011, Morales, Calvo & Bialystok, 2013, Namazi & Thorardottir, 2010).

However, to our knowledge, the existing research has not been extended to second

language learners undergoing bilingual immersion.

The notion of a "bilingual cognitive advantage" arises from cumulated evidence

that bilinguals excel on tasks that rely heavily on executive control (e. g., Adesope et al.,

2010, Bialystok, 2001, Bialystok, 2009). It has been suggested that the origin of this

phenomenon lies in the parallel language activation that arises during bilingual speech

production and comprehension (e.g., Thierry & Wu, 2007, Van Hell & Dijkstra, 2002)

resulting in between-language interference which requires resolution. Controlled

attention for bilingual language processing has been shown to be mediated at least

partially by domain-general executive control mechanisms (for a meta-analysis, see

Luk, Green, Abutalebi & Grady, 2012), and the constant recruitment of these

mechanisms during bilinguals' standard, everyday language processing is thought to

render bilingualism a type of lifelong cognitive training that generalizes to executive

processes beyond the linguistic domain (e. g. Bialystok, 2001). More recently, some

authors have reported failures to replicate bilingual advantages in executive control

(Antón et al., 2014, Duñabeitia et al., 2014, Namazi & Thorardottir, 2010, Paap &

Greenberg, 2013), suggesting that perhaps this universal account lacks precision, and

that the outcome of the between-group comparisons may depend on additional factors

such as task-specific demands, bilingual population, or executive process in question.

In terms of specific target executive functions and mediating processes, the

overall pattern of results is somewhat difficult to interpret because, for one, no single

valid model of executive functions exists. A popular account that has often been referred

to in the bilingual advantage literature identifies shifting or switching attention between

tasks or mental sets ("Shifting"), updating and monitoring of representations in WM

("Updating"), and controlled inhibition of prepotent responses ("Inhibition") as

distinguishable, key mechanisms of executive control (Miyake, Friedman, Emerson,

Witzki & Howerter, 2000). The components work in inseparable unison during task

performance. From this theoretical perspective, WM is closely related to executive

functioning, especially its updating component, as it refers to the online storage and

manipulation of information (Baddeley & Hitch 1974) and provides the capacity for the

maintenance of goal-related information necessary to coordinate task-relevant processes

(Miyake et al.,, 2000). The conceptual overlap between WM and executive control is

corroborated empirically by virtue of a close reciprocal relationship between measures

of WM and executive control (McCabe, Roediger, McDaniel, Balota & Hambrick,

2010).

However, WM entails both executive and nonexecutive components or subprocesses

(Baddeley & Hitch, 1974, Gathercole, Pickering, Ambridge & Wearing, 2004).

Measures of WM differ in the relative degree to which they draw on domain-general

executive control or domain-specific verbal or visuo-spatial storage. To assess WM

performance, many researchers refer to either complex span procedures like reading

span or operational span (Daneman & Carpenter, 1980), which combine recall with a

secondary task, or versions of the n-back task (Cohen et al., 1997), where participants

are required to evaluate sequentially presented stimuli for a match at a given lag (1-

back, 2-back or 3-back). Both families of tasks tap into the updating and monitoring

aspect of WM (Schmiedek, Hildebrandt, Lövdén, Wilhelm & Lindenberger, 2009).

However, while complex span paradigms provide a more balanced measure of executive

processing and short-term storage capacity (e.g., Bayliss, Jarrold, Gunn & Baddeley,

2003), the n-back task is thought to mainly reflect the updating component of executive

functioning (Cohen et al., 1997, Miyake et al., 2000).

Beyond task-specific demands, separate WM components show independent developmental curves in school-aged children (Gathercole et al., 2004) and may be modulated differentially by developmental factors like bilingualism. This is crucial when exploring bilingual effects on WM because developmental bilingualism may come with costs in the linguistic domain. For example, monolinguals tend to score higher on tests of receptive or productive vocabulary than age-matched bilingual toddlers (Poulin-Dubois, Bialystok, Blaye, Polonia & Yott, 2012), preschool and school-aged children (e.g., Bialystok, Luk, Peets & Yang, 2010), and adults (e.g., Bialystok & Luk, 2012), and bilingual children and adults show more difficulties and slower reaction times in lexical access and lexical retrieval (e.g., Ivanova & Costa, 2008, Yan & Nicoladis, 2009). Importantly, this phenomenon extends to bilinguals' L1 and can be observed in sequential bilinguals after being immersed in a weaker L2 (Linck, Kroll, & Sunderman, 2009). Thus, while domain-general executive processes operating on WM may benefit from a general executive advantage, domain-specific verbal storage may be negatively affected by linguistic costs (Luo, Craik, Moreno & Bialystok, 2012). In sum, WM performance in bilinguals may be influenced by two counteracting effects that cancel each other out, ultimately placing bilinguals at the same overall level as their monolingual peers (Bialystok & Feng, 2009).

Existing research into bilinguals' WM performance reflects this ambiguity. Generally speaking, superior bilingual-to-monolingual performance tends to be observed when the relative executive demand is high. For example, on a variation of the Simon task that combined varying demands for WM and conflict resolution, five- and seven-year-old bilinguals were better able to handle increased WM load than

monolinguals of the same age, even in the absence of conflict (Morales et al., 2013). In addition, bilingual participants of both age groups outperformed their monolingual peers on (complex) visual WM span. Regarding verbal updating, Carlson and Meltzoff (2008) reported a bilingual advantage once socioeconomic status and verbal abilities - where bilinguals were at disadvantage – had been statistically controlled for. On the other hand, no differences were observed when comparing bilingual and monolingual preschool children, school-aged children, adolescents or young adults on verbal, visuo-spatial, or symbolic memory (Bonifacci, Giombini, Bellocchi, & Contento, 2011, Engel de Abreu, 2011, Namazi & Thorardottir, 2010). All of the latter studies used simple span procedures, adding only minimal manipulation of the digits retained in WM (e. g., backwards span), and thus relatively minor executive demands (see Engle, Tuholski, Laughlin & Conway, 1999). This factor, in combination with putative linguistic disadvantages in bilinguals, may account for the mixed pattern of results.

Few studies have tried to extend these findings to second language learners attending bilingual immersion schooling (emergent bilinguals). In fact, the research by Carlson and Meltzoff (2008) has been the only one to assess this particular subgroup on a WM updating task. In terms of other aspects of executive functioning, the limited number of studies that exists seems to suggest that an executive advantage may emerge, but is constrained by how long a child has been immersed in the L2. Thus, compared to age-matched monolingual controls, no between-group differences emerged for children after 6 months (Carlson & Meltzoff, 2008), or 12 months of bilingual immersion (Poarch & van Hell, 2012). However, after having undergone bilingual immersion for three years, a group of eight year old emergent bilinguals outperformed their monolingual peers on a range of executive measures (Nicolay & Poncelet, 2013, for a longitudinal replication, Nicolay & Poncelet, 2015). In line with this gradient, within a

group of children attending the same bilingual immersion school, a reduction in

interference cost was related to balanced proficiency and length of time the child had

been enrolled in the school (Bialystok & Barac, 2012). In sum, according to previous

evidence, one might expect emergent bilinguals immersed in an L2 at school to show a

relative benefit in WM if i) the task taps into central executive processes and ii) they

have been immersed for a minimum duration.

In addition, based on the discussion regarding possible linguistic costs of

bilingualism, and the involvement of domain-specific verbal resources in some WM

tasks, it is possible that bilingual advantages only emerge if the WM task has relatively

low linguistic demands. However, while there is some research extending the patterns of

results regarding executive function from early bilinguals to L2 immersion students,

there is less evidence as to whether the typical linguistic costs might also extend to this

type of bilingualism, in particular, whether any consequences emerge for children's

dominant L1. Research with adult sequential bilinguals showing slowed lexical access

in the L1 as a consequence of L2 immersion suggests this might be the case (Linck et

al., 2009). On the other hand, even with fulltime immersion programs, L2 immersion

students typically return to a dominant L1 environment outside of school every day.

Overall, it is currently unclear whether linguistic costs for the L1 can be observed in

emergent bilingual children in L2 immersion schooling, and whether these costs might

extend to verbal WM.

The present research

The main aim of the present research was to explore the development of WM in

school aged children attending bilingual immersion versus monolingual schools in an

otherwise monolingual community. Children were tested on two measures of verbal

WM in their L1, an n-back task with letters, and reading span. Both combine executive

and linguistic demands, but differ in the relative degree to which they rely on these sub-

processes. Generally speaking, the executive load of the n-back task is higher, especially

in regards to updating (i.e., continually monitoring and refreshing items held in WM)

and interference control (i.e., managing interference from items that are currently

irrelevant, but had been relevant in a preceding trial and may become relevant again).

The reading span task places higher demands on linguistic processes, and is affected by

factors such as verbal processing speed (Bayliss et al., 2003). In terms of different WM

components, reading span is a balanced measure of the domain-general executive

central and domain-general verbal storage, while the n-back task mainly reflects central

executive processes (Bayliss et al., 2003, Schmiedek et al., 2009). Importantly, these

differences are relative: the n-back task also involves processing and storage of verbal

information, and the reading span task requires updating and interference control, but to

a lesser degree than the respective other task. Our aim in selecting these two tasks was

thus to identify and dissociate executive (beneficial) and linguistic (detrimental)

consequences of emerging bilingualism for WM performance. Given that it is currently

unknown whether the linguistic deficits found in early, balanced bilinguals (e.g.

Bialystok, 2001) extend to L1 performance in immersion students, we additionally

included two language tasks to measure vocabulary and lexical access. Our predictions

were as follows. If L2 immersion students experience the same pattern of linguistic

costs and executive benefits that has been reported for early, balanced bilinguals, we

would expect monolingual children to score higher than their bilingual peers on

measures of vocabulary and lexical access. We might further expect emergent bilinguals

to show superior performance on the n-back task, an indicator of executive updating,

while reading span, which has higher linguistic demands than the n-back task, might not

show any between-group discrepancies, because an advantage in executive control might be cancelled out by linguistic processing costs.

Children were attending grade 2, 3, 5 or 8 at the time of testing. These age groups represent critical stages in the developmental trajectory of WM as well as the cumulative experience with bilingualism. Critical developmental stages are achieved with a qualitative shift around the age of seven to eight (grades 2-3) when children start to spontaneously engage in phonological rehearsal (e.g., Gaillard, Barrouillet, Jarrold & Camos, 2011), and with the beginning of adolescence (around age 11, grade 5), as the components of WM and their coordination begin to function an adult-like fashion (e.g., Gathercole et al., 2004). Further quantitative increases continue until later in adolescence. In addition, children in the second grade have been immersed in their L2 for a year and a half, the duration for which cognitive consequences started to become detectable in previous research (Poarch & van Hell, 2012). We expected both age-related and immersion-related changes in WM performance to be more pronounced in younger children, and therefore included consecutive age groups in the lower grades and fewer selected groups of older children.

Method

Participants

Participants were 152 children (70 boys and 82 girls) who were recruited as part of a large scale research project cognition and education. At the time of testing, 38 children were attending the second grade, 42 the third grade, 42 the fifth grade and 30 the eighth grade. All participants were native speakers of Spanish, the language of testing; half of them (*n* = 76) were attending a fulltime English immersion program

(bilinguals), the other half (n = 76) a monolingual Spanish school (monolinguals).

There were equal numbers of bilingual and monolingual children within each grade

level. Monolingual and bilingual children were matched for age and gender. Students

with dyslexia, ADHD or other developmental disorders, and children who had been

exposed to a language other than Spanish outside of school were excluded from the

sample.

Bilinguals had been immersed in the English language since the beginning of

first grade. For this group, all school activities and instructions were in English, except

for Spanish language and literature classes, which were taught in Spanish. In the first

and second grade, children had 27.5 hours of L2 immersion per week. Third and fourth

graders had 26.5 weekly hours of L2 immersion, and in grades 5 through 8, children had

22.5 hours of L2 English immersion. In addition, all children (bilinguals and

monolinguals) started foreign language classes in French in grade 5, with 3 hours per

week. Classroom instruction and communication in the monolingual program was

entirely in Spanish, with the exception of foreign language instruction in English (up

until grade 4: 2h/week, starting from grade 5: 3 hours/week) and French. The two

groups were compared on a number of background measures (see Table 1 for

descriptive statistics).

[Insert Table 1]

As an index of SES, we obtained questionnaire scores for parents' educational

level. A parent's score reflects their highest diploma obtained, distinguishing between

graduates of university level (5), vocational training (4), high school (3),

secondary/middle school (2) and elementary school (1) institutions. Separate values

were obtained for paternal and maternal education and were submitted to χ^2- likelihood

ratio tests. In addition, we assessed parental investment in home literacy environment

(HLE). Questions regarding HLE were included in a family questionnaire (e. g.: "We

encourage our child to read."), and four answer categories were provided for each item:

Never (0), sometimes (1), almost always (2), and always (3). Sum scores were subjected

to two-way factorial ANOVAs with the factors age and language status. Fluid

intelligence was measured by means of the K-BIT matrices subscale (Kaufman &

Kaufman, 2000), a paper and pencil test of fluid and crystallized intelligence. We used

raw scores to compare performance.

The overall level of socioeconomic status and home literacy environment was

high in both groups. χ^2-likelihood ratio tests revealed no monolingual-versus-bilingual

differences regarding paternal or maternal education, indicating similar SES across the

families of bilingual and monolingual children (maternal education level across age

groups; $\chi^2(4) = 1.83$, $p > .05$, grade 2: $\chi^2(4) = 2.1$, $p > .05$, grade 3: $\chi^2(4) = 5.01$,

$p > .05$, grade 5: $\chi^2(4) = 2.36$, $p > .05$, and grade 8: $\chi^2(4) = 2.43$, $p > .05$; paternal

education level across age groups: $\chi^2(4) = 6.59$, grade 2: $\chi^2(4) = 1.72$, $p > .05$, grade 3:

$\chi^2(4) = 6.17$, $p > .05$, grade 5: $\chi^2(4) = 0.83$, $p > .05$, and grade 8: $\chi^2(4) = 6.44$, $p > .05$).

The ANOVA on HLE scores revealed no significant differences in function of language

status, $F(1, 144) = 1.71$, $p > .05$, $\eta_p^2 = .03$, or age, $F(3, 144) = 1.79$, $p > .05$, $\eta_p^2 = .01$,

and no interaction, $F(3, 144) = 1.08$, $p > .05$, $\eta_p^2 = .02$. For fluid intelligence, the effect

of age was significant, $F(3, 144) = 31.83$, $p < .001$, $\eta_p^2 = .40$, but the effect of language

status, $F(1, 144) = 2.73$, $p > .05$, $\eta_p^2 = .02$, and the interaction, $F(3, 144) = 0.77$,

$p > .05$, $\eta_p^2 = .02$, were not.[1]

Procedure

Participants were tested individually in a quiet room of their school. The tasks

were presented in a fixed order (K-BIT subscales, rapid automatic naming, n-back, reading span) over two separate experimental sessions, each one lasting 45 minutes. All computerized tasks were presented using E-Prime 2.0 software (Schneider, Eschman & Zuccolotto, 2002), except for the rapid automatic naming task, which was run using DMDX (Forster & Forster, 2003). Instructions read by a female native speaker of Spanish were recorded and presented over headphones at test. The instructions were repeated until the experimenter was able to confirm that the children had understood the task. Questionnaires regarding socioeconomic status, HLE and home language use were distributed at test for the children to have a parent or primary caregiver fill them out at home, and were recollected during the following test session. Teacher questionnaires including information regarding age, grade level, history of learning disorders, or other relevant diagnoses were completed by the class teachers during school breaks. Informed consent was obtained from parents or legal guardians prior to testing.

Experimental tasks and variables

[Insert Table 2]

Vocabulary

Expressive vocabulary knowledge was measured using the vocabulary subtest of the K-BIT (Kaufman & Kaufman, 2000). We used raw scores to assess performance.

Rapid automatic naming

The Rapid Automatic Naming (RAN) task served as an approximation to verbal processing speed. In this task, participants are required to name six recurring letters and objects that are arranged in a random order as fast as possible. Serial naming reflects

lexical retrieval and phonological lexical access (Wolf, 1986) and is less related to vocabulary knowledge than discreet naming, because only a very limited number of items per category (e. g., objects) are tested.

Reading Span

The Reading Span task was based on a Spanish version of Daneman and Carpenter's task (1980) that was adapted for children (García-Madruga et al., 2013). Participants are presented with a set of simple sentences and, upon completion of a set, are asked to recall the last word of all sentences. Sentence length was restricted to 8-9 words. The number of sentences presented within a set increased over consecutive blocks, starting from two and going up to six. Instructions were followed by a practice block. Correct and incorrect answers were recorded by the experimenter on an answer sheet. The final word of a set was to never be recalled first. The procedure yields a reading span score between 2 and 6.

N-back

We used the same version of the n-back task as described by Pelegrina and colleagues (2015). The task consisted of four blocks, 0-back, 1-back, 2,-back and 3-back (the 0-back block served for practice purposes only), and items to be updated were letters. Each level of the task (0-back, 1-back, etc.) was preceded by instructions, an example consisting of six trials, and a practice block. Practice blocks were repeated until a child reached a correct percentage of 60%, and if on any task level this percentage was not reached, the procedure was ended. We calculated the sum of correct answers for each block (children who had not reached the cutoff level on a given block, and had therefore not proceeded any further on the task, received no points for the

omitted blocks).

Results

All statistical analyses reported were two-tailed, and alpha set to .05.

Language-based development

Language-based development was assessed in terms of vocabulary and rapid naming. To measure vocabulary, we considered raw scores. For the RAN score, overall RTs from the object and letter categories were averaged to obtain a combined score. We carried out two separate ANOVAs with the factors age and language status. Unsurprisingly, the main effect of age was significant for both vocabulary, $F(3, 144) = 46.78$, $p < .001$, $\eta_p^2 = .49$, and rapid naming, $F(3, 144) = 36.42$, $p < .001$, $\eta_p^2 = .43$. For vocabulary, there were no significant bilingual-versus-monolingual differences, $F(1, 144) = 1.32$, $p > .05$, $\eta_p^2 < .01$, but monolinguals were significantly faster than bilinguals in rapid naming, $F(1, 144) = 5.32$, $p < .05$, $\eta_p^2 = .04$. The interaction between age and language status was not significant for either vocabulary, $F(3, 144) = 1.20$, $p > .05$, $\eta_p^2 = .02$, or RAN, $F(3, 144) = 1.0$, $p > .05$, $\eta_p^2 = .02$. There were significant linear trends for the effect of age on both variables, vocabulary, $F(1, 64) = 197.08$, $p < .001$, $\eta_p^2 = .76$, and RAN, $F(1, 64) = 120.33$, $p < .001$, $\eta_p^2 = .65$. Figure 1 illustrates language-based development over age.

Given that the developmental course of the linguistic abilities underlying rapid naming appeared to differ between monolingual and bilingual children, we carried out planned contrasts for consecutive age levels within each group. Effects of age were significant for both bilinguals, $F(3, 72) = 18.27$, $p < .001$, $\eta_p^2 = .43$, and monolinguals, $F(3, 72) = 19.23$, $p < .001$, $\eta_p^2 = .45$. Bilinguals' performance increased only marginally

between the 2nd and 3rd grade, F (1, 38) = 3.57, p = .07, $\eta_p{}^2$=.09, whereas monolinguals

showed a large, significant increase, F (1, 38) = 13.35, p = .001, $\eta_p{}^2$=.26. On the other

hand, bilinguals' performance showed a significant increase between grades 3 and 5, F

(1, 40) = 5.2, p = .03, $\eta_p{}^2$=.12, but monolinguals' performance did not, F (1, 40) = 1.75,

p >.05, $\eta_p{}^2$=.04. Both groups improved significantly between grades 5 and 8, Fs (1, 34)

$\geq$ 8.3, $p \leq$ .007, $\eta_p{}^2 \geq$ .20. The difference between bilinguals and monolinguals reached

significance in grade 3, F (1, 40) = 4.60, p =.04, $\eta_p{}^2$=.10 (all other Fs $\leq$ 2.06, ps > .05).

[Insert Figure 1]

Working Memory

Two separate ANOVAs with the factors age and language status were conducted,

with scores for correctly recalled items on the n-back by block and reading span scores

as dependent variables. For the n-back task, block was included as an additional

variable. For age-related changes in WM performance, see Figures 2 (n-back) and 3

(reading span).

N-back

The main effect of block, F^2 (1.64, 236.39) = 181.71, p < .001, $\eta_p{}^2$=.56, and its

interaction with age, F (4.93, 236.39) = 2.98, p = .01, $\eta_p{}^2$=.06, were significant,

indicating stronger age effects as the task increased in difficulty (see figure 2, ps < .001,

for all linear trends). However, block did not interact with any other variable (Fs

$\leq$ .2.22, ps > .05, η_ps$^2 \leq$ .02). We further observed main effects of age, F (3, 144) =

15.32, p < .001, $\eta_p{}^2$=.24, with older children outperforming younger ones as confirmed

by a linear trend, F (1, 64) = 38.87, p <.001, $\eta_p{}^2$ = .38, and language status, F (1, 144) =

5.85, p = .02, $\eta_p{}^2$=.04, with bilinguals outperforming monolinguals.

[Insert Figure 2]

Although the interaction between age and language status was not significant, F (3,144) = 1.92, $p > .05$, $\eta_p{}^2 = .04$, additional analyses[3] and visual inspection of the group means suggested that the effect of language status was age-dependent. To better understand these developmental patterns, we conducted a series of follow-up ANOVAs by language status and age. Given that block did not interact with language status or its interactions, for the sake of simplicity, n-back scores were collapsed across block for these analyses.

Effects of age on n-back scores were significant for both bilingual, F (3, 72) = 5.49, $p = .002$, $\eta_p{}^2 = .19$, and monolingual children, F (3, 72) = 11.31, $p < .001$, $\eta_p{}^2 = .32$. According to planned contrasts for consecutive age levels, bilinguals' performance increased significantly from the 5th to the 8th grade, F (1, 34) = 11.24, $p = .002$, $\eta_p{}^2 = .25$. Monolinguals showed a significant increase between grades 3 and 5, F (1, 40) = 12.73, $p = .001$, $\eta_p{}^2 = .24$, and a marginally significant increase between grades 5 and 8, F (1, 34) = 3.97, $p = .05$, $\eta_p{}^2 = .11$. None of the other contrasts were significant, all Fs ≤ 0.11, ps $> .05$, $\eta_p{}^2$s $< .01$. Separate ANOVAs by age revealed that the effect of language status was marginally significant in grade 2, F (1, 36) = 3.87, $p = .06$, $\eta_p{}^2 = .10$, and significant in grade 3, F (1, 40) = 6.92, $p = .01$, but not in grade 5 or 8, Fs ≤ 0.64, $p > .05$, $\eta_p{}^2 \leq .02$. That is, a bilingual advantage was observed before, but not after monolinguals showed a developmental leap in task performance.

Reading Span

Reading span scores (see task description) were also subject to a significant effect of age, F (3, 144) = 11.94, $p < .001$, $\eta_p{}^2 = .20$, with older children performing

better than younger ones, as indicated by a significant linear trend, F (1, 64) = 32.03, p

<.001, $\eta_p{}^2$ = .33. Bilinguals and monolinguals performed at the same overall level, F (1,

144) = .01, p > .05, $\eta_p{}^2$ <.01, but there was a significant interaction between age and

language status, F (3, 144) = 2.92, p = .04, $\eta_p{}^2$ =.06[4].

[Insert Figure 3]

Follow-up ANOVAs by language status showed significant age effects for

bilinguals, F (1, 72) = 11.06, p < .001, $\eta_p{}^2$=.32, and monolinguals, F (1, 72) = 3.34, p

= .02, $\eta_p{}^2$=.12. The developmental course for this task differed for both groups as in

monolinguals, a marginally significant improvement was observed between grades 2

and 3, F (1, 38) = 3.59, p = .07, $\eta_p{}^2$=.09, while bilinguals' performance increased at a

later stage, between grades 3 and 5, F (1, 40) = 14.26, p = .001, $\eta_p{}^2$=.26. None of the

other planned contrasts between consecutive grade levels were significant, Fs $\leq$ 2.20,

p > .05, $\eta_p{}^2$ <.06. ANOVAs by age showed marginal effects of language status in 3rd

grade, F (1, 40) = 3.76, p = .06, $\eta_p{}^2$=.09, where monolinguals reached higher scores, and

5th grade, F (1, 40) = 3.02, p = .09, $\eta_p{}^2$ =.07, where bilinguals performed better. Thus,

the outcome of the between-group comparison changed after bilinguals showed an age-

related increase. No significant between-group differences were observed for 2nd

graders, F (1, 36) = .86, p > .05, $\eta_p{}^2$ =.02, or 8th graders, F (1, 28) = .65, p > .05, $\eta_p{}^2$

=.02.

Correlations

In order to corroborate the assumption that reading span is more related to verbal

processing than the n-back task, we calculated partial correlations between WM tasks

and rapid naming (where bilinguals had scored lower than monolinguals) for the entire

sample while controlling for the effect of age. Reading span proved to be significantly correlated with RAN scores, $r = -.17$, $p = .04$, but n-back scores did not ($r = -.02$, $p > .05$). The relationship between n-back and reading span scores did not reach significance either ($r = .01$, $p > .05$).

Discussion

The aim of this research was to explore the development of WM performance in school age and assess whether emergent bilingual children immersed in an L2 at school show developmental modulations. To that end, we compared children aged seven through 14 who were enrolled in the second, third, fifth, or eighth grade of an L2 immersion school to monolinguals of the same age on two measures of WM. Research into the cognitive consequences of L2 immersion education is still scarce, although this type of schooling has been gaining popularity. Our goal was to build on previous findings (e.g. Bialystok & Barac, 2012, Nicolay & Poncelet, 2013) to fill this gap. Although the present study was cross-sectional as most research on bilingualism and cognitive control, we aimed to ensure that both groups be as similar as possible in factors other than language status, including age, gender, SES, fluid intelligence and home literacy environment. Main effects of age for measures of linguistic and WM performance confirm that the selected tasks are sensitive measures of individual differences in the cognitive development of children this age in the respective domains.

Our parting hypothesis was that emergent bilingualism – the onset of multiple language use and acquisition – is associated with both cognitive advantages (i.e., enhanced cognitive control) and deficits (i.e., delayed or impaired language skills), and that both are relevant for WM performance (see also Bialystok, 2009). We thus predicted that i) emergent bilinguals might lag behind their monolingual age-peers on

language tasks in the L1, and that ii) emergent bilinguals would excel on a WM task that places high demands on executive control and is linguistically less demanding (n-back task). Finally, we predicted that if both linguistic costs and executive advantages occur in emerging bilinguals, the two groups might show similar performance on a WM task that places equal demands on executive and non-executive linguistic processes (i.e., reading span).

Regarding verbal processing in the L1, we found that emergent bilingual children were significantly slower than their monolingual counterparts, as evidenced by reaction times on the rapid automatic naming task, although it should be noted that this difference was only significant for third graders. This finding stands in line with previous research showing relatively slower lexical access in bilinguals (e.g., Ivanova & Costa, 2008, Yan & Nicoladis, 2009), especially slowed L1 processing as a consequence of L2 immersion in sequential bilingualism (Linck et al., 2009). To our knowledge, this research is the first one to extend these findings to children immersed in the L2 at school. On the other hand, both groups showed similar levels of vocabulary knowledge, suggesting a dissociation of knowledge-based and processing-based aspects of language development. A similar pattern was observed by Yan and Nicoladis (2009), who report greater difficulties with lexical access, combined with monolingual-like vocabulary scores in school-aged (balanced) bilinguals. Within-language vocabulary scores of bilingual children depend on the exposure time to each language (Genesee & Nicoladis, 2007), while the difficulty in lexical access and retrieval can be explained as being due to the added cognitive load from the second language during bilinguals' language processing (Yan & Nicoladis, 2009).

In regards to WM updating, we observed a bilingual advantage in the younger

age groups (grades 2 and 3), although no between-group differences were observed for older children (grades 5 and 8). Although our version of the n-back task uses verbal content, it is a relatively pure measure of executive WM updating. The finding for younger emergent bilinguals is thus consistent with previous research showing an executive advantage in L2 immersion students (e.g., Bialystok & Barac, 2012, Nicolay & Poncelet, 2013), as well as research with early bilinguals using WM tasks that were high in executive load (Carlson & Meltzoff, 2008, Morales et al., 2013). This finding suggests that emergent bilingualism may alter the developmental trajectories of WM-related processes, rather than ultimate achievement as such (we will come back to this point). Previous research with immersion students has often been limited to younger children within the first three years of L2 immersion (e.g., Nicolay & Poncelet, 2013, 2015, Poarch & van Hell, 2012), so it is unclear to what extent the lack of between-group differences for older immersion students is consistent or inconsistent with these studies.

Reading span requires executive control, but at the same time, relies more heavily on linguistic processing. In line with some previous research (e.g. Blom, Küntay, Messer, Verhagen, & Leseman, 2014), we postulated that putative bilingual costs and benefits would cancel each other out, and predicted no between-group differences for this task. Memory falls unto a middle ground in terms of bilingual costs and benefits: as executive and linguistic processes both affect performance, the relative outcome compared to monolinguals depends to the extent to which a task draws on either (see Bialystok, 2009). Our results indicate the greatest age-related outcome differences for this task. In particular, younger bilinguals (grade 3) who outperformed their monolingual age-peers on the n-back task, showed a marginal disadvantage on the reading span task. It seems that the linguistic deficit in bilingual children at this age

level showed through on the reading span task as it requires a relatively high level of linguistic functioning. This dissociation suggests that is important to consider the specific task content, that is, the relative contribution of executive and non-executive components, to the outcome when comparing bilinguals and monolinguals on WM paradigms. A recent study suggests that linguistic deficits can affect bilinguals' performance on WM negatively on tasks tapping both central executive and domain-general verbal components, although contrary to our research, verbal WM was tested in bilinguals' less dominant L2 (Blom et al., 2014).

As mentioned above, it is important to note that between-group differences emerged at certain grade levels. While the interaction with age was only significant for reading span, further comparisons revealed that the language effects for the n-back task and rapid automatic naming were also clearly driven by differences in younger age groups. Thus, our data suggest that L2 immersion may boost or delay WM processes at earlier developmental stages, but all children eventually reach a similar level of performance (see Morales et al., 2013, for a similar interpretation). A comparison of age effects within-group confirmed that immersion students in grades 2 and 3 performed the n-back task at a level that monolinguals did not reach until the 5th grade. The pattern for the reading span task was reversed, as monolinguals showed increased performance between grades 2 and 3 and bilinguals lagged behind until later on (grade 5). Similarly, monolinguals' naming performance showed a large and reliable improvement between grades 2 and 3, while the age-related reduction in bilinguals was significant later on, between grades 3 and 5. Together, data from these two tasks suggest that linguistic processing abilities develop earlier in monolinguals whereas they develop more progressively in emergent bilinguals. Both groups also showed increased performance in rapid naming between the 5th and 8th grade, suggesting that speed and fluency of

lexical access continue to increase substantially into adolescence but at this stage,

development in monolingual children and immersion students proceeds similarly.

Again, this suggests that rather than affecting ultimate attainment, becoming immersed

in a second language can alter the developmental course of language-based abilities.

The lack of between-group differences in the higher grades may be surprising, as one

might expect that with longer exposure to a bilingual immersion environment, cognitive

consequences in terms of measurable effects should increase. On the other hand, it is

plausible that younger bilinguals who are still new to interacting in their less dominant

L2 experience the largest transfer effects, as cross-language interference and executive

control demands should be particularly high at this stage. Cognitive consequences of

bilingualism tend to be most easily detectable in developmental stages of less-than-

optimal executive performance, that is, childhood and old age (Craik & Bialystok,

2006) and training effects in the context of executive function generally tend to be

larger at earlier intervention and developmental stages (Diamond & Lee, 2011).

Conclusion

In conclusion, the present research offers several contributions to understanding

WM development and bilingualism. We report one of the first studies to investigate the

cognitive consequences of emergent bilingualism through L2 immersion at school and

extend some of the findings from early bilinguals to this group. In regards to the nature

of WM development, our data suggest that WM is more susceptible to modulatory

effects at earlier stages. Thirdly, we show that WM tasks that differ in the relative

contribution of sub-components may lead to different outcomes of a between-group

comparison. WM is a multi-component construct (e.g., Baddeley & Hitch, 1974,

Gathercole et al., 2004,), and our findings highlight the importance of considering the

specific task content, and ideally, to use several alternative tasks that allow one to

estimate differences at the level of sub-components. The important question remains

whether the specific modulations have practical consequences. Further study is needed

in order to determine whether any of these effects show transfer into other cognitive

abilities and domains. This should prove a fruitful field for future research.

Footnotes

[1]Although there were no differences between bilingual and monolingual children in any of the control variables, we additionally compared the two groups within each age group. Overall there were no differences due to language status in these control variables in most comparisons ($ps > .05$) except for fluid intelligence in the oldest age group $F(1, 28) = 28.44$, $p < .001$, $\eta_p^2 = .50$, and for HLE in the second age group, $F(1, 40) = 4.66$, $p = .04$, $\eta_p^2 = .10$. To ensure these differences did not influence the results, we performed parallel ANCOVAs with HLE and fluid intelligence as covariates for all analyses on N-back, Reading span, Vocabulary, and RAN scores; the outcome in regards to all data patterns was the same as for the ANOVAs reported in the upcoming results section.

[2]Degrees of freedom for within-subject effects were corrected using the Greenhouse-Geisser correction.

[3]ANOVAs for combined age groups (younger children in grades 2 and 3 vs. older children in grades 5 and 8) confirm main effects of age, $F(1, 148) = 30.21$, $p < .001$, $\eta_p^2 = .17$, and language status, $F(1, 148) = 4.75$, $p = .03$, $\eta_p^2 = .03$, as well as a significant interaction, $F(1, 148) = 4.42$, $p = .03$, $\eta_p^2 = .03$. Comparing the effect of language status within the two broader age groups revealed that younger bilingual children, $F(1, 78) = 9.72$, $p < .01$, $\eta_p^2 = .11$, but not in older ones, $F(1, 78) = .003$, $p > .05$, $\eta_p^2 < .05$, outperformed monolinguals on the n-back task.

[4]ANOVAs with combined age groups confirmed the effect of age, $F(1, 148) = 29.33$, $p < .001$, $\eta_p^2 = .17$ and the significant interaction between age and language status, $F(1, 148) = 7.44$, $p = .007$, $\eta_p^2 = .05$. The effect of language status remained non-significant, $F(1, 148) = 0.01$, $p > .05$, $\eta_p^2 < .01$. Younger children had better reading span scores

than their bilingual age peers, $F(1, 78) = 4.48$, $p = .04$, $\eta_p^2 = .05$, while in older children,

there was a tendency towards a bilingual advantage, $F(1, 78) = 3.08$, $p = .08$, $\eta_p^2 = .04$.

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Captions for Figures

Figure 1. (a) Mean vocabulary expressed as raw scores and (b) rapid automatic naming (RAN) in seconds, for monolingual (ML) versus bilingual (BL) children divided by age. Error bars represent the standard error of the mean.

Figure 2. N-back scores (overall sum of correct responses) for monolingual (ML) versus bilingual (BL) children, divided by age for a) the 1-back, b) the 2-back, and c) the 3-back block. Error bars represent the standard error of the mean.

Figure 3. Mean reading span for monolingual (ML) versus Bilingual (BL) children, divided by age. Error bars represent the standard error of the mean.

Table 1

Socioeconomic status and fluid intelligence

	Maternal Education		Paternal Education		Home Literacy Environment		Fluid Intelligence	
Grade	Bilinguals	Monolinguals	Bilinguals	Monolinguals	Bilinguals	Monolinguals	Bilinguals	Monolinguals
2nd	5	5	5	5	2.11 (0.03)	2.05 (0.04)	24.42 (0.94)	24.16 (1.20)
3rd	5	5	5	5	2.28 (0.04)	2.02 (0.03)	26.96 (1.04)	26.38 (0.78)
5th	5	5	5	4	2.20 (0.03)	2.27 (0.03)	34.41 (0.84)	32.90 (3.03)
8th	5	5	5	5	2.08 (0.04)	2.02 (0.03)	39.53 (0.68)	35.00 (0.51)
TOTAL	**5**	**5**	**5**	**5**	**2.18 (0.05)**	**2.09 (0.03)**	**30.86 (0.80)**	**29.33 (1.03)**

Note. Socioeconomic status and general cognitive level of monolingual as compared to bilingual children by age. Group medians for maternal and paternal education are based on a 5-point scale with (5) - College +, (4) - Vocational Training, (3) - High School, (2) - Secondary/Middle School, (1) - Elementary School level degree. Values for home literacy environment express group means for the frequency of literacy-related activities at home, with (0) - Never, (1) - Sometimes, (3) - Almost always, (4) - Always. Parenthesized values represent the respective standard errors of the mean.

Table 2

Working memory and linguistic development

Grade	Bilinguals	Monolinguals	Bilinguals	Monolinguals	Bilinguals	Monolinguals
	1-back		2-back		3-back	
2nd	30.21 (1.36)	26.11 (1.68)	25.16 (1.26)	17.53 (2.89)	14.53 (3.08)	9.95 (2.91)
3rd	30.48 (1.64)	26.29 (1.49)	24.71 (2.15)	16.29 (1.85)	16.29 (2.51)	6.71 (2.13)
5th	30.43 (1.42)	33.29 (1.22)	25.86 (1.85)	17.86 (1.90)	17.86 (3.13)	17.57 (3.28)
8th	36.00 (0.60)	35.67 (0.84)	32.93 (1.05)	29.07 (2.54)	29.07 (1.18)	25.53 (2.87)
TOTAL	**31.49 (0.73)**	**30.03 (0.83)**	**26.76 (0.93)**	**23.33 (1.28)**	**18.80 (1.47)**	**14.24 (1.61)**

Grade	Reading Span		Vocabulary		Rapid Automatic Naming	
2nd	2.72 (0.12)	2.88 (0.12)	40.05 (1.49)	41.16 (1.10)	32.80 (1.08)	31.78 (1.39)
3rd	2.83 (0.17)	3.35 (0.21)	45.67 (1.12)	45.05 (1.05)	29.28 (1.47)	25.30 (1.13)
5th	3.69 (0.16)	3.32 (0.14)	52.54 (2.70)	51.96 (1.47)	25.27 (0.96)	23.48 (0.79)
8th	3.93 (0.28)	3.66 (0.18)	61.47 (1.33)	56.40 (1.15)	20.91 (0.62)	20.46 (0.55)
TOTAL	**3.26 (0.11)**	**3.29 (0.09)**	**49.28 (1.26)**	**48.22 (0.89)**	**27.40 (0.93)**	**25.46 (0.74)**

Note. Mean scores and standard errors (parenthesized) for WM and linguistic tasks in monolingual compared to bilingual children, divided by age.