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The effects of L2 exposure at school on the cognitive development of children from monolingual backgrounds: A longitudinal study*

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Abstract

This longitudinal study examined the cognitive development of Spanish children from monolingual backgrounds attending schools with varying levels of English exposure (13%-83%), to assess whether higher L2 exposure results in advantages over time. 229 children (ages 6-7) completed background (non-verbal reasoning, working memory, L1 vocabulary, L2 vocabulary) and experimental tests measuring attentional/executive functions (selective attention, divided attention, switching, inhibition) at the beginning and end of Year 1 of Primary Education. Generalized linear mixed-effects models, accounting for factors such as family educational level, onset of L2 exposure, and language exposure outside of school, indicated that children's cognitive skills benefit from (high) L2 exposure at school, with greater L2 exposure being linked to more enhanced attentional/executive skills as well as to a larger L2 vocabulary. These findings support the positive effects of immersion programs, suggesting that L2 exposure in school settings alone can contribute to more developed attentional/executive skills.

Key words: cognitive development; attention; executive functions; educational bilingualism; longitudinal

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1. Introduction

The cognitive effects of child bilingualism continue to be a debated issue in bilingualism research. While there is evidence supporting cognitive benefits in certain executive functions (Bialystok & Martin, 2004; Cape et al., 2018; Costa et al., 2008; Hernández et al., 2013), the reliability or extent of these benefits is sometimes questioned, as other external factors may also influence outcomes (Duñabeitia et al., 2014; Paap et al., 2015). Moreover, most of this literature is based on cross-sectional studies (Bialystok & Barac, 2012; Poarch & van Hell, 2012) or examines children raised with two languages at home or in the community (De Cat, 2020; Shokrkon & Nicoladis, 2021), making it difficult to identify the amount of exposure needed for potential advantages to develop, or to extend the results to other populations such as children exposed to educational bilingualism.

The present study is longitudinal and examines executive function skills in Spanish (L1) children from monolingual backgrounds, attending schools with different English (L2) exposure levels, namely, non-bilingual, bilingual, and immersion[1]. Our aim is to explore whether children from schools with higher L2 exposure reveal cognitive advantages over time.

1.1 Bilingualism and cognitive development

Executive function skills refer to domain-general cognitive processes such as inhibitory control (the ability to suppress dominant or automatic responses and resist distractions), cognitive flexibility (the capacity to switch between different tasks or mental frameworks), and monitoring (the ability to manipulate and update information in working memory (WM)) (Miyake & Friedman, 2012; Miyake et al., 2000). Bialystok (2010) suggests that bilinguals have enhanced cognitive abilities due to the frequent need to switch between languages and inhibit one while using the other. A large body of research suggests that bilingualism can enhance inhibition and cognitive flexibility (Bialystok & Shapero, 2005; Bialystok et al., 2004; Bialystok & Barac, 2012; Costa et al., 2008; Garbin et al., 2010; Hansen et al, 2016; Prior & MacWhinney, 2010; Tran et al., 2019; Zeng et al., 2019). However, more attention has been paid to measuring inhibition than cognitive flexibility (see Planckaert et al., 2023). Some evidence in favor of enhanced inhibition in simultaneous and early sequential bilinguals has been obtained using common conflict-resolution tasks such as the Simon task, the Stroop task, or the Flanker task (Bialystok & Barac, 2012; Diaz & Farrar, 2018; Gerstadt et al., 1994; Grote et al., 2021; Verhagen et al., 2017). To examine cognitive flexibility, researchers have used measures like the Dimensional Change Card Sort (DCCS) or the Opposite Worlds task, where participants must focus their attention and switch between different rules. Here, too, advantages have been found for simultaneous and sequential bilinguals (Bialystok, 1999; Bialystok et al., 2010; Castillo et al., 2022; Prior & MacWhinney, 2010; Tran et al., 2019), with stronger evidence found in younger children (up to age 6) (Planckaert et al., 2023).

Other studies have failed to replicate the so-called ‘bilingual advantage’. For instance, a US study by Arizmendi et al. (2018) found no evidence of an advantage for inhibition, shifting, or updating in 7-9-year-old Spanish-English bilinguals. Children attended English-only schools but spoke Spanish at home. The authors suggest that although these children were proficient in both languages, they may not have had enough opportunities to switch between languages for a bilingual advantage to materialize. Shokrkon and Nicoladis (2021) also failed to find a cognitive flexibility advantage in Mandarin Chinese-English bilingual preschoolers. They replicated key aspects of Bialystok and Martin’s (2004) study, which had originally found a bilingual advantage using the DCCS, and tested 4-5-year-olds on this task but did not observe the same effects. More recently, Troesch et al. (2023) conducted a longitudinal study examining executive functioning among 332 children who grew up as simultaneous bilinguals, sequential bilinguals, or German monolinguals in Switzerland at ages 4, 6, and 7. The results did not indicate a bilingual advantage for selective attention.

Planckaert et al. (2023) provide an overview of research on inhibition and switching in bilingual children under 12 years old, in which they show that advantages in these skills were more frequently observed during a critical age (3-6), with benefits favoring younger bilinguals for both inhibition and switching. The authors suggest that discrepancies in findings may stem from differences in experimental designs (e.g., cross-sectional vs. longitudinal), the types of tasks employed (e.g., delay vs. conflict tasks), and the age groups studied (e.g., critical vs. post-critical periods in children, young vs. ageing adults).

Research failing to replicate a bilingual advantage suggest that previous studies may have overlooked important factors that can affect cognitive functioning in this population, such as families' educational background, immigrant status, onset/type/amount of L2 exposure, L2 proficiency, and language-switching frequency (Arizmendi et al., 2018; Duñabeitia et al., 2014; Engel de Abreu et al., 2012; Green & Abutalebi, 2013; Paap et al., 2015; Shokrkon & Nicoladis, 2021; Troesch et al., 2023). These variations shape the bilingual experience and affect the impact of bilingualism, which can also vary depending on the type and extent of bilingual exposure (e.g., sequential vs. simultaneous bilingualism). Here, we focus on educational bilingualism, where children are educated in two languages but not raised bilingually at home or the community.

1.2 Educational bilingualism

A few studies have been conducted on the potential cognitive benefits of early L2 acquisition through bilingual or immersion education[2]. Bialystok and Barac (2012) carried out two studies: the first involved children in Grades 2 and 3 enrolled in a Hebrew L2 immersion program, and the second included children in Grades 2 and 5 in a French L2 immersion program. In both studies, longer exposure to the immersion language was associated with better task switching and interference inhibition skills.

In a cross-sectional study, Nicolay and Poncelet (2013) found that 8-year-old children enrolled in an English immersion program for 3 years outperformed those enrolled in a French monolingual school in tasks assessing alerting, selective attention, divided attention, and mental flexibility, but not on response or interference inhibition tasks. They used the Test for Attentional Performance for Children (KiTAP) (Zimmermann et al., 2002) and the Attentional Network Test (Fan et al., 2002), and the groups were matched for age, verbal reasoning, non-verbal reasoning (NVR), and socio-economic status (SES). The same authors (Nicolay & Poncelet, 2015) conducted a follow-up study to rule out the possibility that the cognitive advantages observed in the immersion group were due to pre-existing differences. They addressed this by testing 51 5-year-olds at the start of an English immersion program and 50 5-year-olds in a monolingual French program, assessing both groups from a baseline. The results confirmed that 3 years of immersion resulted in cognitive benefits in attention and mental flexibility measures (response inhibition and interference inhibition was not re-evaluated, as previous results had not shown significant effects for these skills). The authors suggest that such benefits arise from the dual challenge of learning new academic content while simultaneously acquiring the L2. In these demanding environments, children compensate for their limited L2 fluency by relying more heavily on attentional control, which appears to enhance their overall cognitive abilities, particularly in areas related to focus and task management.

Following this research, Barbu et al. (2019) conducted a study with 8-year-olds to test whether the same effects could be observed after one year of immersion. They tested 59 French children enrolled in an English immersion program and 57 children attending a monolingual French school. To assess cognitive functioning, they also used the KiTAP, which measures alerting, selective attention, divided attention, and cognitive flexibility. They found an advantage in the selective auditory attention task, but not in alerting, divided attention, or cognitive flexibility. The authors argue that one year of immersion may not be enough to positively impact all skills. The enhanced auditory attention observed in immersed children may have resulted from adaptations to their learning environment. Immersion students face the challenge of having to process complex academic input in a language they are not fluent in, while monolinguals do not encounter the same cognitive demands, as they learn their subjects in a 'highly automatized and fluent' language. Notably, 30 of the 59 immersed children in this study received 50% of their school subjects in English (and the rest 75%), unlike Nicolay and Poncelet (2013, 2015), where all children were exposed to 75% of their courses in English.

More recently, Chamorro and Janke (2023) conducted a longitudinal study to examine the cognitive development of 59 Spanish children enrolled in bilingual English-Spanish programs or non-bilingual programs. Children were grouped according to their exposure to the L2 (English) at school: high exposure (40%), low exposure (30%), and monolingual (10%). They were tested at the end of Years 1 and 2 of Primary Education (PE) on the complete battery of the Test of Everyday Attention for Children (TEA-Ch2; Manly et al., 2016) and several background measures (NVR, WM, L1 vocabulary, L2 vocabulary). Results showed that bilingual children, particularly those in the high exposure group, outperformed their monolingual peers in L2 vocabulary in both years, and that there were no group differences in L1 vocabulary. Bilingual advantages were also observed in Year 1 in tasks relating to interference suppression and response inhibition, although these seemed to disappear after the second year (see also Chamorro & Janke, 2020, 2021). Interestingly, children who reported having exposure to English outside of school outperformed those who did not in tasks involving interference suppression in Year 2.

Some studies within the field of bilingual education, however, have found no evidence of cognitive advantages when comparing executive functions in monolingual and bilingual children (Carlson & Meltzoff, 2008; Kaushanskaya et al., 2014; Poarch & van Hell, 2012; Simonis et al., 2020). For instance, Kaushanskaya et al. (2014) compared two groups of 7-year-old English children in the US attending either a monolingual program or a bilingual program with a 90-10 Spanish-English model. The bilingual children had an average of 1.96 years of dual-immersion experience, while the monolingual group had no L2 exposure. Both groups were matched for age, gender, and SES. Using a version of the DCSS, the authors failed to find an advantage in task switching in the bilingual group. Relatedly, Purić et al. (2017) did not find differences for interference inhibition or switching in a study comparing three groups of 7-year-old Serbian-speaking children with different L2 exposure levels: high-exposure (5 hours/day), low-exposure (1.5 hours/day), and a monolingual group. A more recent study by Simonis et al. (2020) compared 128 10-year-old French-speaking children learning L2 Dutch or English with 102 same-age monolingual French children of the same age. The immersion programs provided 12-15 hours/week of L2 exposure. They found no bilingual advantage on cognitive flexibility or inhibition after 5 years of immersion. This finding contrasts with earlier studies (Nicolay & Poncelet, 2013, 2015) and suggests that immersion benefits might also depend on factors such as the intensity of the immersion program, the frequency and type of language switching (see Verreyt et al., 2016), or the timing when cognitive advantages become apparent (see also Nicolay & Poncelet, 2013, 2015; Paap, 2018).

A few studies have focused on minority languages. For instance, Cape et al. (2018) compared executive function skills in two groups of 9-10-year-old children: 29 in Gaelic-medium education and 30 in English-medium education, all of whom had been exposed to English from birth. Using tasks from the TEA-Ch (Manly et al., 1999), they found that

Gaelic-medium students outperformed their peers in response inhibition but not in task switching, which the authors interpret as being the result of the bilingual experience of children, who are restricted to the minority/second language at school. With one clear dominant language throughout the day, they do not engage in frequent language switching but rather have to make a big effort to suppress their dominant language. This suppression resembles response inhibition rather than switching (see also Costa et al., 2009; Green & Abutalebi, 2013; Prior & Gollan, 2011).

Other studies have documented an advantage in children attending bilingual education on skills other than executive control, such as NVR (Woumans et al., 2016), abstract thinking (Planas, 2014; Salekhova & Tuktamishov, 2019), novel-word learning (Kaushanskaya & Rechtzigel, 2012), and WM (Bialystok et al., 2008; Kaushanskaya et al., 2014; Luo et al., 2013; Purić et al., 2017; Trebits et al., 2021). With regards to L1 development, research shows that enrollment in immersion programs does not hinder L1 skills (Björklund & Mård-Miettinen, 2011; Bostwick, 2001; Ha, 2001; Mehisto & Asser, 2007; Serrano & Howard, 2003). While children may experience a temporary lag when first entering bilingual or immersion programs, this is typically short-lived, and studies have consistently shown that L1 skills remain strong and continue to develop alongside the L2 (Lambert et al. 1973; Montanari, 2013; Padilla et al., 2013). In his review of immersion programs, Genesee (2004) concluded that L1 development is not negatively impacted by immersion education. He observed that students in bilingual programs, including students from low SES backgrounds and those with below-average academic abilities, typically achieve L1 proficiency levels comparable to their peers in monolingual programs. Trebits et al. (2021) also suggested that bilingual education can mitigate the disadvantages often found in children with low SES. This is a particularly important finding when considered with studies that have shown how

SES-related differences can influence children's cognitive development and academic achievement (see also Lindholm-Leary, 2014; Luo et al., 2021).

In conclusion, the number of discrepant studies in the field of educational bilingualism (and child bilingualism in general) has grown in recent years. These findings suggest that disparate bilingual experiences result in various possibilities for advantages across different aspects of executive functions. Further, targeted research would help clarify the picture for educational bilingualism. Longitudinal studies are particularly important here as they can offer more information regarding the developmental trajectories followed by children exposed to bilingualism in the context of bilingual/immersion schools.

1.3 The present study

Considering the controversial findings with regards to child bilingualism in general and educational bilingualism in particular, the present study aimed to explore the potential benefits of different amounts of L2 exposure at school for the cognitive development of children educated bilingually yet raised in monolingual backgrounds. Our research contributes to the existing literature by investigating this issue longitudinally and controlling for a large number of variables (age, gender, family educational level, immigration status, other languages spoken at home[3], age of first exposure to English, exposure to English outside of school, exposure to other languages outside of school) and background measures (L1 vocabulary, L2 vocabulary, WM, NVR), with the aim of meeting the methodological concerns mentioned in the previous section and exploring more closely the cognitive repercussions of amount and length of L2 exposure in this population.

To achieve this, we recruited children from several schools, where different amounts of L2 exposure were provided, and engaged them in tasks at the start and end of Year 1 of PE to track their development and answer the following research questions:

(1) Does higher L2 exposure at school confer more enhanced attentional/executive skills on children from monolingual backgrounds? If so, do these advantages remain constant, increase, or disappear over time?

(2) Is children's performance on the attentional/executive measures associated with any of the background measures (L1 vocabulary, L2 vocabulary, WM, NVR) or the other variables (age, gender, family educational level, immigration status, other languages spoken at home, age of first exposure to English, exposure to English outside of school, exposure to other languages outside of school)?

2. Method

2.1 Participants

A total of 231 typically-developing Spanish children from 10 different schools in Madrid took part in the initial testing phase at the beginning of Primary 1 (T0). Nine months later, in the testing phase at the end of Primary 1 (T1), 229 of the original children participated again, as two children had left their respective schools. Children were classified as sequential bilinguals (see Footnote 3) because they had been exposed to Spanish (their L1) at home and to English (their L2) through formal education. However, we controlled for several language acquisition-related variables (age of onset of L2 exposure, L2 exposure outside of school, exposure to other languages outside of school, other languages spoken at home) to ensure any relevant differences could be accounted for (see Section 2.4)[4].

Children were recruited from the three types of schools found in the Spanish educational system, which represent the different levels of L2 exposure available. Four schools followed a non-bilingual program, with a curriculum entirely in Spanish except for 3 hours of English Language per week, which equated to 13.33% of their instruction in English. Five schools followed a bilingual program, with a curriculum in English that varied between schools, ranging from 32% to 41.11%. One school followed an immersion program, with a curriculum entirely in English except for 4.5 hours of Spanish Language per week, which equated to 82.86% of English exposure (see Table 1 for participant numbers, age range and mean per type of school at T0 and T1). These schools included 6 state schools (3 non-bilingual, 3 bilingual), 3 semi-private schools (1 non-bilingual, 2 bilingual), and 1 private school (the immersion school).

<Insert Table 1 about here>

2.2 Materials

Background measures

We measured children's NVR, WM, and receptive vocabulary in both L1 and L2. For NVR, we used the Raven's Coloured Progressive Matrices (Raven, Raven, & Court, 1998), where children are shown a series of visual patterns and asked to identify the missing piece from the six options provided. For WM, the Forward Digit Span task (FDS) from the Wechsler Intelligence Scales for Children-Revised (WISC-R; Wechsler, 1974) was used, where children are read sequences of numbers and asked to repeat them in the same order. To monitor children's receptive vocabulary, we employed the Test de Vocabulario en Imágenes Peabody (PPVT-III; Dunn et al., 2006) for Spanish (L1) and the British Picture Vocabulary Scales (BPVS3; Dunn & Dunn, 2009) for English (L2). Except for WM, where the span was used, raw scores were used in the analyses for all background measures to retain the full range of individual differences in performance (see Section 2.4).

The same tests were re-administered by the same researchers at T1 to track children's development and evaluate whether the amount of English exposure received at school influenced their performance on any of the other background measures or on the attentional/executive tasks.

In addition, parents/guardians completed a questionnaire that gathered relevant information on SES and language background (e.g., immigrant status, family educational level, languages spoken at home, children's amount and type of language exposure outside of school)[5].

Experimental measures

To assess cognitive skills, children completed a standardized and normed clinical battery of attentional and executive tests (TEA-Ch). We selected 5 tasks (7 measures) to assess 4 types of attentional/executive functions (selective attention, divided attention, switching, response inhibition). Each task is explained below, in the order completed by the children as recommended by the test administration manual:

(1) SkySearch (selective attention): Children must find as many targets (pairs of identical spaceships) as possible on a sheet filled with distractors (pairs of different spaceships). The timing score is based on both accuracy and time taken to complete the task.

(2) SkySearchDT (divided attention): Children perform two tasks simultaneously: finding spaceships on a sheet (as in SkySearch) and counting sounds they hear on a recording. The timing score accounts for both accuracy and time taken to complete the task.

(3) CreatureCounting (switching): Children are presented with a sequence of 'creatures' along a path, interrupted with arrows pointing up or down (7 trials). They count the creatures aloud, switching to counting upwards or downwards based on the arrows encountered. Two separate measures are recorded: accuracy (number of trials where counting is correct) and timing (average taken in those accurate trials - only provided if there was a minimum of 3 correct trials).

(4) Walk/Don'tWalk (response inhibition): Children are asked to mark steps along a path, using a pen, after each tone they hear on a recording (20 trials). Unpredictably, one tone ends differently from the rest, signaling them to stop. The test measures whether the child is able to stop marking when this signal occurs or is 'carried away' into a task-driven 'automatic' style of responding (accuracy).

(5) OppositeWorlds (switching): Children are presented with strings of digits '1' and '2'. The digits must be read as presented in the same-world (congruent condition) but in the opposite-world (incongruent condition), '1' must be read as '2' and '2' as '1'. There are 4 trials (2 for the same-world, 2 for the opposite-world), providing 2 timing measures: congruent and incongruent. The speed with which the children perform the cognitive reversal (incongruent) is the crucial measure.

All tasks start with practice trials. They were not computerized. Timing was recorded manually using the stopwatch provided with the test, following the administration manual.

2.3 Procedure

Before testing started, written consent was obtained from schools and parents. Together with the consent form, parents completed the background questionnaire in advance of our visit and they were collected upon arrival. Child assent was also obtained by explaining the tasks in a child-friendly way and ensuring their understanding and continued willingness to participate. Breaks were provided as needed/requested. Children completed the tasks individually in a quiet room at their respective schools. The tasks were administered over three 30-minute sessions, which took place on different days, each administered by a different trained and experienced researcher. In Session 1, children completed the Raven's, WM, and BPVS tests, in that order, with one researcher. In Session 2, a different experimenter administered a Theory-of-Mind task[6], followed by the PPVT. In Session 3, they completed the TEA-Ch with a third researcher.[7] All tasks were conducted in Spanish, as this was the children's L1, except for the BPVS, which was administered by an English native speaker.

2.4 Analyses

Statistical analyses were conducted using the R statistical platform (version 4.1.1, R Core Team, 2021). Data were analyzed using Generalized Linear Mixed Models (GLMMs) using the glmmTMB package. Separate models were fitted for each background measure (L1 vocabulary, L2 vocabulary, NVR, WM) and each attentional/executive task (seven measures)[8]. Models were first fitted for data at T0, followed by models for the comparison between T0 and T1 scores. The primary independent variable in each analysis was the amount of English exposure at school, with time (T0, T1) and its interaction included for the time point comparison.

Initially, a baseline model for each outcome measure was fitted including several covariates: age, gender, family educational level (as a proxy for SES), age of first exposure to English, other languages spoken at home, weekly exposure to English outside of school, and weekly exposure to other languages outside of school[9]. The models comparing performance over time include a random intercept for subjects to account for repeated measures. Subsequent analyses involved equating multiple GLMMs to ascertain the most suitable model for the data. Interaction terms were included initially but removed if not significant. However, the main effects of time and English at school and their interaction remained in the models regardless of their significance. Each model employed the maximal random effects structure that would converge (Barr et al., 2013). We report significant main effects and interactions below. Full model outputs are included in the Supplementary Materials.

3. Results

3.1 Background measures

First, we report the results of the background measures at T0, which enabled us to check whether the different schools showed any significant differences at the start of their PE. Then, we present the results that compare changes in performance from T0 to T1[10].

Initial analyses on the background measures confirmed that all groups were matched for age, NVR, WM, and L1 Spanish vocabulary, but not for L2 English vocabulary (β=0.025, *SE*=0.002, *z*=9.187, *p*<.001), where children at schools with higher L2 levels of exposure achieved higher scores (see means and SDs in Table 2). This was not surprising as 84.85% of the children had attended Preschool in their respective schools and had therefore been exposed to different amounts of English before starting PE (i.e., immersion>bilingual>non-bilingual). However, to confirm that differences in L2 vocabulary were indeed linked to this earlier L2 exposure, we examined this relationship in the children that attended Preschool. We found a significant positive association between L2 exposure at school and L2 vocabulary (β=0.034, *SE*=0.003, *t*=10.92, *p*<.001), indicating that children who had attended Preschool in those schools with greater English exposure were the ones who achieved higher L2 vocabulary scores.

<Insert Table 2 about here>

After analyzing the initial data collected at T0, models were run to analyze each background measure comparing scores between T0 and T1, with English at school, time, and their interaction, as fixed effects, while also accounting for the covariates. All models revealed a significant improvement over time, i.e., scores in all background measures were significantly higher at T1 than at T0 (p_s<.05). Means and SDs for background measures at T1 are provided in Table 3 and improvement of each group from T0 to T1 in Figure 1.

<Insert Table 3 about here>

<Insert Figure 1 about here>

For NVR, the model yielded no significant main effect of English at school (β=-0.004, *SE*=0.003, *z*=-1.305, *p*=.192). However, it revealed a positive effect for age (β=0.882, *SE*=0.145, *z*=6.046, *p*<.001), with older participants having higher NVR scores. Additionally, both L1 (β=0.246, *SE*=0.047, *z*=5.165, *p*<.001) and L2 vocabulary (β=0.113, *SE*=0.056, *z*=1.987, *p*=.046) were positively associated with Raven's, suggesting that greater vocabulary in both languages is linked to better performance on NVR.

Similarly, there was no main effect of English at school on WM (β=0.008, *SE*=0.002, *z*=0.337, *p*=.735). The model revealed significant effects of parent education (β=0.436, *SE*=0.168, *z*=2.589, *p*=.009) and L1 vocabulary (β=0.148, *SE*=0.036, *z*=4.038, *p*<.001), suggesting that higher education and greater L1 vocabulary are linked to enhanced WM.

For L2 vocabulary, results revealed that higher L2 exposure at school led to increased gains in this measure (β=0.025, *SE*=0.002, *z*=10.865, *p*<.001), although the effect of English at school slightly decreased over time, as indicated by the interaction between L2 exposure and time (β=-0.005, *SE*=0.003, *z*=-2.189, *p*=.029) (see Figure 2[11]). This suggests that while children with increased L2 exposure continued to increase their vocabulary over time, the gap between groups with different levels of exposure narrows between T0 and T1. In addition, age (β=0.465, *SE*=0.092, *z*=4.951, *p*<.001) and parent education (β=0.551, *SE*=0.162, *z*=3.571, *p*<.001) emerged as significant covariates, meaning that older children and those with parents with higher education performed significantly better in L2 vocabulary. Exposure to English outside of school also had a positive effect on L2 vocabulary (β=1.036, *SE*=0.186, *z*=5.588, *p*<.001), indicating a significant benefit from extra-curricular language use.

<Insert Figure 2 about here>

In contrast, English at school had a marginally negative effect on L1 vocabulary (β=-0.006, SE=0.003, z=-1.796, p=.073), with participants in schools with higher L2 exposure performing marginally worse on this measure (see Figure 3). Other effects were observed for gender (β=-0.193, SE=0.096, z=-2.000, p=.045), with females performing better than males, and parent education (β=1.202, SE=0.235, z=5.112, p<.001), with children whose parents have higher levels of education achieving better L1 vocabulary scores. Similarly, performance on the Raven's (β=0.206, SE=0.039, z=5.188, p<.001) positively influenced L1 vocabulary, indicating that higher NVR is associated with stronger vocabulary skills. L2 exposure outside of school revealed a negative association with L1 vocabulary (β=-0.556, SE=0.268, z=-2.072, p=.038), suggesting that children with more English exposure outside of school had a smaller Spanish vocabulary.

<Insert Figure 3 about here>

3.2 Attentional and executive measures

The models analyzing each attentional/executive measure at T0 (see Table 4)[12] included English at school as a fixed effect along with the aforementioned covariates. The results revealed significant differences for 'English at school' in five of the seven measures.

<Insert Table 4 about here>

The main effect of English at school was significant in *SkySearch* (selective attention) (β=-0.004, SE=0.002, z=-2.438, p=.015), suggesting that greater L2 exposure is associated with lower timing scores. The model also revealed significant effects of PPVT (β=-0.105, SE=0.032, z=-3.280, p=.001) and Raven's (β=-0.105, SE=0.032, z=-3.339, p=.001), that is, higher scores on L1 vocabulary and NVR are associated with better performance. Gender was also significant (β=0.123, SE=0.062, z=1.986, p=.047), with male participants performing better than females.

English at school did not yield a significant main effect for *SkySearchDT* (divided attention) (β=-0.002, *SE*=0.001 *z*=-1.19, *p*=.235). However, age of exposure to English (β=-0.073, *SE*=0.012, *z*=-3.720, *p*<.001), Raven's (β=-0.147, *SE*=0.029, *z*=-5.10, *p*<.001), and FDS (β=-0.127, *SE*=0.042, *z*=-3.01, *p*=.002), emerged as significant covariates, suggesting that earlier onset of L2 exposure, higher NVR, and higher WM are associated with lower timing scores.

Similarly, for *CreatureCounting* (switching), English at school did not influence the accuracy scores (β=-0.002, *SE*=0.004, *z*=-0.591, *p*=.554). However, BPVS emerged as a significant predictor (β=0.249, *SE*=0.087, *z*=2.872, *p*=.004), indicating that higher L2 vocabulary scores are associated with greater accuracy in this task. Interestingly, the model for *CreatureCounting-timing*[13] revealed a main effect of English at school (β=-0.004, *SE*=0.002, *z*=-3.130, *p*=.002), suggesting that greater L2 exposure is associated with lower timing scores. Age also emerged as a significant covariate (β=-0.268, *SE*=0.083, *z*=-3.211, *p*=.001), indicating that older children tend to perform this task faster. Additionally, higher Raven's scores led to lower timing scores (β=-0.051, *SE*=0.024, *z*=-2.146, *p*=.031), while exposure to English outside of school was associated with slower performance (β=0.236, *SE*=0.105, *z*=2.249, *p*=.024).

The model for *Walk/Don'tWalk* (response inhibition) showed a significant main effect of English at school (β=0.035, *SE*=0.010, *z*=3.130, *p*=.001). This indicates that children attending schools with higher levels of English exposure achieved higher scores. The model also revealed significant effects of Raven's (β=0.733, *SE*=0.228, *z*=3.216, *p*=.001) and FDS (β=0.764, *SE*=0.351, *z*=2.176, *p*=.029), with higher NVR and WM being associated with better performance.

Finally, the models fitted for *OppositeWorlds* (switching) revealed a main effect of English at school in both the congruent (β=-0.031, *SE*=0.001, *z*=-4.95, *p*<.001) and incongruent (*β*=-0.003, *SE*=.001, *z*=-4.46, *p*<.001) conditions. In the congruent condition, higher NVR (*β*=-0.064, *SE*=0.013, *z*=-5.07, *p*<.001) and WM scores (*β*=-0.054, *SE*=0.017, *z*=-3.11, *p*=.002) were linked to better performance. The incongruent model also revealed a significant effect of Raven's (*β*=-0.045, *SE*=0.014, *z*=-2.67, *p*=.007) and PPVT (*β*=-0.037, *SE*=0.015, *z*=-2.52, *p*=.012), indicating that higher NVR and L1 vocabulary are associated with lower timings.

The results on attentional/executive measures are in line with what was found for L2 vocabulary, as within those children who had previously attended Preschool in their respective schools (84.85%), those who had been exposed to higher L2 levels had a larger L2 vocabulary (see Section 3.1). This can explain why at T0 we already see that higher English exposure at school correlates with better performance in most of the attentional/executive tasks.

Next, models were run to evaluate changes in attentional/executive skills over time (T0 vs. T1). They included English at school, time, and their interaction as fixed effects, along with the covariates. Across all models, overall performance significantly improved over time (p_s<.05), while English at school had a significant main effect on six of the seven attentional/executive measures (see Table 5 for descriptive statistics).

<Insert Table 5 about here>

For *SkySearch*, there was again a positive main effect of English at school (*β*=-0.003, *SE*=0.002, *z*=-2.01, *p*=.044). The model also revealed that males outperformed females (*β*=0.103, *SE*=0.045, *z*=2.26, *p*=.024), and that higher levels of parental education are associated with quicker performance (*β*=-0.226, *SE*=0.111, *z*=-2.04, *p*=.042). Furthermore, both L1 vocabulary (*β*=-0.069, *SE*=0.025, *z*=-2.74, *p*=.006) and Raven's (*β*=-0.081, *SE*=0.024, *z*=-3.42, *p*<.001) were significant predictors, with higher scores associated with faster performance.

As in T0, there was no main effect of English at school on *SkySearchDT* (β=-0.001, SE=0.001, z=-1.53, p=.127), though a small positive interaction with time suggested a slight cumulative benefit over time (β=0.003, SE=0.002, z=2.00, p=.045). Age of exposure to English had a negative effect (β=-0.029, SE=0.012, z=-2.30, p=.022), which suggests that earlier onset of exposure to English is associated with faster timing responses. Raven's (β=-0.076, SE=0.018, z=-4.15, p<.001) and FDS (β=-0.055, SE=0.025, z=-2.20, p=.027) were also predictors of this task, with children with higher NVR and greater WM capacity revealing a better performance.

For *CreatureCounting*, results showed a significant positive effect of English at school on the accuracy scores (β=0.008, SE=0.004, z=2.620, p=.009). However, the negative interaction revealed between English at school and time (β=-0.009, SE=0.003, z=-2.973, p=.003) suggests that the impact of English at school on performance decreased over time, indicating that while higher L2 exposure was associated with better accuracy, this initial benefit lessened from T0 to T1 (see Figure 4). Raven's (β=0.146, SE=0.036, z=4.092, p<.001) and BPVS (β=0.148, SE=0.046, z=3.243, p=.001) emerged as significant covariates, indicating that higher NVR and larger L2 vocabulary are associated with better performance. As for *CreatureCounting-timing*, the model revealed a significant positive effect of English exposure at school (β=-0.004, SE=0.001, z=-3.130, p=.002), suggesting that higher L2 exposure is associated with faster task completion. Several covariates significantly influenced performance. Females outperformed males, as indicated by their lower timing scores (β=-0.134, SE=0.043, z=-3.121, p=.002). Age also played a role, with older participants performing better (β=-0.211, SE=0.053, z=-4.022, p<.001). Additionally, family education showed a small effect (β=0.204, SE=0.098, z=2.090, p=.037), suggesting that children from families with lower educational levels were slightly quicker at completing this task. Since this model only included data from the 64 children who were able to achieve, in T0, the minimum score of 3 in the *CreatureCounting-accuracy* task needed to gain a score in the timing task, a second model was run, which included all the children that achieved this score in T1. The second model included 175 participants and, again, a significant effect of English at school was found (β=-0.002, *SE*=0.001, *z*=-2.20, *p*=.027), as well as a positive effect of NVR (β=-0.048, *SE*=0.019, *z*=-2.47, *p*=.013).

<Insert Figure 4 about here>

In *Walk/Don'tWalk*, English at school positively influenced performance, revealing that higher L2 exposure is associated with higher accuracy (β=0.040, *SE*=0.011, *z*=3.742, *p*<.001). The model showed significant positive effects of L1 vocabulary (β=0.594, *SE*=0.189, *z*=3.146, *p*=.002) and Raven's (β=0.561, *SE*=0.172, *z*=3.259, *p*=.001).

In *OppositeWorlds*, English at school was associated with faster performance in both the congruent (β=-0.003, *SE*=0.001, *z*=-5.33, *p*<.001) and incongruent conditions (β=-0.003, *SE*=0.001, *z*=-4.333, *p*<.001). An increase in the benefit of English at school over time was observed in the congruent condition (β=0.001, *SE*=0.000, *z*=2.28, *p*=.023), with a marginally significant effect in the incongruent condition (β=0.001, *SE*=0.001, *z*=1.951, *p*=.051) (see Figure 5). Additional positive predictors in both conditions included Raven's (congruent: β=-0.044, *SE*=0.008, *z*=-5.36, *p*<.001; incongruent: β=-0.036, *SE*=0.010, *z*=-3.422, *p*=.006) and WM (congruent: β=-0.029, *SE*=0.011, *z*=-2.56, *p*=.010; incongruent: β=-0.027, *SE*=0.013, *z*=-2.051, *p*=.040). PPVT played a role in the incongruent condition (β=-0.024, *SE*=0.011, *z*=-2.145, *p*=0.031), with children with greater L1 vocabulary performing better.

<Insert Figure 5 about here>

4. Discussion

The present study investigated the potential cognitive benefits of L2 exposure at school in children raised in monolingual backgrounds. To this end, a total of 231 children from different types of schools (non-bilingual, bilingual, immersion) with varying levels of L2 exposure (13.33%-82.86%) were assessed using a battery of background and attentional/executive measures at the beginning (T0) and end (T1) of Year 1 of PE. We addressed two main research questions: (1) Does higher L2 exposure at school confer more enhanced attentional/executive skills on children from monolingual backgrounds? If so, do these advantages remain constant, increase or disappear over time?; (2) Is children's performance on the attentional/executive measures associated with any of the background measures (L1 vocabulary, L2 vocabulary, WM, NVR) or the other variables (age, gender, family educational level, immigration status, other languages spoken at home, age of first exposure to English, exposure to English outside of school, exposure to other languages outside of school)?

4.1 Background measures

The testing phase at T0 enabled us to confirm that children from all schools started PE matched on age, NVR, WM, and L1 vocabulary. However, already at this stage, their L2 vocabulary differed, with children from schools with higher levels of English exposure exhibiting a larger L2 vocabulary. In addition, of those children who had previously attended Preschool in their respective schools (84.85%), those who had been exposed to higher L2 levels had a larger L2 vocabulary. This finding suggests that higher levels of L2 exposure during Preschool years is enough to develop children's L2 vocabulary to a larger extent than those exposed to lower levels and that these differences are already visible at the start of PE.

During the testing phase at T1, we revisited the children 9 months later to administer the same tasks with the aim of tracking their development and exploring whether any initial advantages found would remain constant, increase, or disappear after one academic year. We found that all children had significantly improved their performance from T0 to T1 on the background measures. NVR and WM continued to be unaffected by the different levels of L2 exposure, with L1 vocabulary (and L2 vocabulary for NVR) positively affecting performance on these tasks. Results from previous studies have been mixed, with some indicating a bilingual advantage for NVR (Woumans et al., 2016), others for WM (Hansen et al., 2016, Purić et al., 2017), and others for WM but not NVR (Kaushanskaya et al., 2014; Trebits et al., 2021). However, differences exist between those studies and ours. Focusing on the longitudinal ones, Woumans et al. (2016) tested 35 children who had never been exposed to the L2 prior to entering PE and compared them to 29 monolinguals, while 84.85% of our children had previously attended Preschool in their respective schools, and all of them had received some exposure to the L2, even those in non-bilingual schools (13.33%). Crucially, they did not find a group difference between the bilingual and the monolingual group, only that the bilingual group improved significantly more than the monolingual group from the testing phase at the beginning of the academic year to the testing phase at the end. Trebits et al.'s (2021) children also belonged to either the immersion program (N=16) or the regular program (N=23), with the former receiving considerably more L2 exposure than our bilingual schools (76.77%) (although slightly less than our immersion school) and the latter less than our non-bilingual schools (two 45-minute lessons/week). In addition, they used three tasks from the WISC-IV to assess WM (letter-number-sequencing task, FDS, backward digit span), while we only used the FDS.

Similarly, L2 vocabulary continued to show differences in T1, with participants with higher English exposure at school (as well as those exposed to English outside of school) achieving higher scores. Other studies have also found that L2 exposure in a classroom setting in immersion/bilingual contexts is sufficient to develop children's L2 vocabulary (Kaushanskaya et al., 2014; Simonis et al., 2020), and that higher or earlier L2 exposure at school results in a larger L2 vocabulary (Chamorro & Janke, 2020, 2021, 2023; Uchikoshi, 2014). Interestingly, our results showed that the effect of English at school slightly decreased over time. While children with higher L2 exposure continued to show greater vocabulary over time, children from the lower L2 exposure groups slightly narrowed the gap between them and the higher-exposure children from T0 to T1. Future visits (children's development will be monitored for 3 more years) will prove crucial to continuing to explore L2 development. The effect of English at school might decrease or, as would be expected, increase, with longer exposure to the L2 leading to larger differences between the groups.

Another interesting finding was that, in T1, L1 vocabulary showed a marginal negative effect for children with higher L2 exposure at school as well as a negative effect with those exposed to English outside of school, revealing a slightly smaller Spanish vocabulary for these children. These findings, however, should be interpreted with caution due to their small effect size (and marginal statistical significance in the case of L2 exposure at school) and the lack of further measures assessing expressive vocabulary or grammar. Although most research shows that children's L1 is not negatively affected by bilingual or immersion education (Björklund & Mård-Miettinen, 2011; Bostwick, 2001; Genesee, 2004; Ha, 2001; Mehisto & Asser, 2007; Serrano & Howard, 2003; Woumans et al., 2016), some initial temporary lag in L1 development when children enter these programs is not uncommon (Lambert et al. 1973; Montanari, 2013; Padilla et al., 2013). Therefore, as with L2 vocabulary, it will be important to continue tracking L1 vocabulary in the upcoming years to see whether this negative effect becomes larger or is indeed just a temporary initial lag. Future testing will incorporate additional language measures, including the production of L1 syntactic structures, which will enable us to explore L1 development in more depth.

One more finding with respect to the background measures that deserves attention is that family educational level, which in this study was used as a proxy for SES, emerged as a significant predictor of performance for L1 and L2 vocabulary and WM. Those children with parents with higher educational levels had larger L1 and L2 vocabularies, and higher WM, than children from families with lower educational levels. Other studies have also pointed to the impact of SES in children's performance and development (Calvo & Bialystok, 2014; Genesee, 2004). This finding also highlights the importance of controlling for variables such as this in bilingualism research (see Duñabeitia et al., 2014; Paap et al., 2015).

4.2 Attentional and executive measures

With regards to attentional/executive functions, the L2 exposure children received before PE also seemed to influence this skill, as at T0, children attending schools with higher levels of English performed better in five out of the seven measures employed. Advantages were found in those measures assessing selective attention, switching, and response inhibition, but not in the task examining divided attention. As with the background measures, at T1, all children had significantly improved in their performance on all attentional/executive tasks since T0. In addition, the L2 exposure at school variable influenced one more measure than it had in T0 (six out of seven), with divided attention (assessed by one measure: *SkySearchDT*) once again being the only one that showed no significant differences. Therefore, children exposed to a higher amount of English at school performed better in all the other measures: selective attention (assessed by one measure: *SkySearch*), switching (assessed by four measures: *CreatureCounting-accuracy, CreatureCounting-timing, OppositeWorlds-congruent, OppositeWorlds-incongruent*), and response inhibition (assessed by one measure: *Walk/Don'tWalk*).

Our findings for selective attention align with previous research, suggesting that early and consistent L2 exposure may promote the ability to focus selectively on relevant information while filtering out distractions (Bialystok, 2010; Chamorro & Janke, 2020; Costa et al., 2008; Nicolay & Poncelet, 2013, 2015). Interestingly, our study found this selective attention advantage before participants had even started PE, suggesting that the benefits emerge early (Preschool years) and are retained after one year of PE. However, other studies with a more limited immersion exposure did not find an advantage in selective attention. For instance, Poarch and van Hell (2012) and Woumans et al. (2016) did not observe such an effect after one year of exposure. Chamorro and Janke (2020), on the other hand, found an advantage for the bilingual group after Year 1 of PE in one of the three tasks that assessed this skill, but this effect disappeared by Year 2 (Chamorro & Janke, 2023). Barbu et al. (2024) did not show a bilingual advantage for selective attention either after two years of exposure to a Content-and-Language-Integrated-Learning program. This suggests that onset of exposure and length of time in an immersion program may be important factors for selective attention gains to be detected in this population.

With respect to switching, our results resonate with previous literature that has suggested that bilingual environments can enhance cognitive flexibility (Bialystok & Martin, 2004; Castillo et al., 2022; Nicolay & Poncelet, 2013, 2015; Prior & MacWhinney, 2010; Tran et al., 2019). With regards to research on bilingual education in monolingual contexts, Nicolay and Poncelet (2013, 2015), which conducted a study very similar to ours, reported benefits in switching in the immersed group after three years of enrollment in this program. Similarly, Bialystok and Barac (2012) found better switching skills in those students with longer exposure to the immersion setting. Barbu et al. (2019), Chamorro and Janke (2020, 2023), and Purić et al. (2017), on the other hand, did not find an advantage for switching, but their children were tested after only one or two years of immersion, which may not have been enough length of exposure. In the present study, we found an advantage after Preschool years for three out of the four measures assessing switching, and after Year 1 of PE for all four measures, for those students with higher L2 exposure at school. This suggests that increased L2 exposure may be necessary for a more enhanced mental flexibility to develop in immersion education in monolingual contexts. Since these students have fewer switching opportunities than bilinguals raised with two languages at home or the community, for example (Bialystok, 1999; Bialystok et al., 2010; Castillo et al., 2022; Prior & MacWhinney, 2010; Tran et al., 2019), length of exposure in this setting seems to be a crucial factor for this skill to develop and for a bilingual advantage to appear.

We also observed a bilingual advantage in response inhibition in T0 and T1, which aligns with other studies that have shown similar advantages in response inhibition using various tasks (Bialystok & Shapero, 2005; Cape et al., 2018; Chamorro & Janke, 2020; Ryan et al., 2004; Zeng et al., 2019). Others, on the other hand, report null results (Carlson & Meltzoff, 2008; Chamorro & Janke, 2020; Martin-Rhee & Bialystok, 2008; Nicolay & Poncelet, 2013). However, Carlson and Meltzoff (2008) and Martin-Rhee and Bialystok (2008) tested simultaneous bilinguals. Compared to the bilingual experience of these bilinguals, children in our study have a clear dominant language (Spanish) which needs to be constantly inhibited. This experience closely resembles the inhibition of a habitual response (see Cape et al., 2018), which is what participants need to do in *Walk/Don'tWalk*. However, a bilingual boost in this skill was not found by other studies on bilingual education, such as Nicolay and Poncelet (2013) or Chamorro and Janke (2020, 2023), who found an advantage after Year 1 of PE for the group with the highest L2 exposure but not after Year 2. On the one hand, Chamorro and Janke's (2020, 2023) children received a maximum of 40% of the curriculum in English (versus the 82.86% that our immersed students received). This suggests that our children have to inhibit their dominant language much more frequently than those in Chamorro and Janke (2020, 2023) and sustain this inhibition for longer as they have all subjects except for Spanish Language in English, which may give them an advantage to successfully perform this task. The experience of Nicolay and Poncelet's (2013) participants is closer to that of our children as they were exposed to 75% of the curriculum in English.

However, their response inhibition task was a *go-no go* test measuring timing response (as well as that of Chamorro & Janke, 2020, 2023), whereas the task used in this study is an accuracy measure. In addition, none of these studies tested children before they started PE as a baseline measure, so it is possible that the lack of effects may be due to initial group differences. These discrepancies in the findings across bilingualism research underscore once again how task demands, bilingual experiences, and participant characteristics, among other factors, may influence whether cognitive advantages develop (and can be detected) in bilingual children.

The lack of an effect for divided attention suggests that this skill may be less sensitive to L2 exposure, possibly due to its reliance on distinct cognitive processes from those involved in selective attention and inhibition (see Miyake et al., 2000). This could indicate that while bilingual education may enhance certain facets of attention, it may require children to focus just on one type of sensory input (i.e., auditory or visual) but not both at the same time (Barbu et al., 2019). Thus, the bilingual classroom experience in this study may not consistently push children to multitask, aligning with previous findings that divided attention benefits often arise when bilinguals face high-level cognitive demands across multiple settings (Costa et al., 2009). That is, being in a bilingual educational setting may not equate to the cognitive challenges of simultaneous bilinguals, for example, who need to adapt to varying demands and contexts, such as conversations with speakers of different languages or bilingual interactions that require quick shifts in focus and attention (Bialystok, 2010; Costa et al., 2009). Notably, our analyses revealed that earlier onset of exposure to the L2 impacted divided attention, suggesting that this skill may be more sensitive to the cognitive demands of early bilingual exposure than simpler tasks like sustained attention (Antón et al., 2014; Bialystok, 2010; Costa et al., 2008). This indicates that timing and amount of L2 exposure may affect attention differently, as specific attention domains may respond variably to the quality versus quantity of bilingual exposure (Barbu et al., 2019; Carlson & Meltzoff, 2008).

Interestingly, NVR emerged as a constant significant predictor in T0 and T1 for all types of attentional/executive functions (in six out of the seven measures in T0, and in all seven measures in T1). Previous studies have also identified a strong connection between NVR and attentional/executive skills (Bialystok & Barac, 2012; Genesee & Gauthier, 1995). WM also emerged as a significant predictor in T0 and T1 for three out of the seven measures. This patterns with previous studies which have indicated that WM capacity supports performance in attention-demanding tasks (Bialystok & Barac, 2012; De Cat, 2020; Verhagen & Leseman, 2016), such as divided attention and switching, as observed in our data. On the other hand, family educational level did not seem to play a major role in attentional/executive measures in our study, which differs from previous research linking SES to cognitive outcomes in bilingual education (Calvo & Bialystok, 2014; Trebits et al., 2021). One possible explanation for the absence of SES effects may be the way it was measured in this study. While we used family educational level as a proxy, other studies, such as Calvo and Bialystok (2014) and Trebits et al. (2021), included several factors, such as parental income, occupation, and access to educational resources, which may have been a more fine-grained SES measure to detect any effects on attentional/executive functions.

Altogether, our findings present a positive picture for monolingually-raised children whose L2 exposure is mostly restricted to the school environment, with advantages being revealed at the early stages of PE in L2 vocabulary and cognitive skills (specifically, selective attention, switching, and response inhibition), especially for those children with higher levels of L2 exposure at school. When interpreted considering other studies on bilingual education, it can be concluded that the length of time in a bilingual education program, the intensity of the bilingual experience, and the proficiency level achieved in the L2 can affect whether benefits in attentional/executive functions show themselves (Carlson & Meltzoff, 2008; Trebits & Kersten, 2019). Therefore, our upcoming testing phases will be crucial to see whether a bilingual effect persists or increases after a longer exposure to immersion education or whether it decreases or disappears and if children from non-bilingual schools catch up with their bilingual peers.

Ethical standard

The authors assert that all procedures contributing to this work comply with the ethical standards of the relevant national and institutional committees on human experimentation and with the Helsinki Declaration of 1975, as revised in 2008.

Competing interest

The authors declare no competing interests.

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Footnotes

[1] See Section 2.1 for an explanation of how we operationalize the terms 'non-bilingual', 'bilingual', and 'immersion' in this study.

[2] Unless otherwise specified, the terms 'bilingual education' and 'immersion education' are used interchangeably in this paper to refer to programs in which subjects other than the second language are delivered in a foreign language, regardless of the percentage of exposure of each language.

[3] Our aim was to recruit students only exposed to Spanish at home. However, given the large number of participating schools and students, to be sure that this was indeed the case, we included questions about the languages that parents/caretakers used at home in our background questionnaire (see Section 2). A small number of families (N=20; 8.66%) reported speaking another language (in addition to Spanish). These children were kept in the study to explore whether they performed differently from the rest. Importantly, the covariate 'other languages spoken at home' was included in the analyses to control for this variable.

[4] For further information on the background variables, see the Supplementary Materials.

[5] No students were excluded from the study, as they performed within the standardized score for the age on the background tests - except for the BPVS, which is expected and consistent with studies on children with L2 English (see Mahon & Crutchley, 2006), the standardized scores being based on L1 speakers.

[6] The Theory-of-Mind data are analyzed in separate work so not further discussed in this paper.

[7] The order of tasks was informed by previous studies (Chamorro & Janke, 2020, 2023) and decided based on their cognitive demands, progressing from more to less demanding tasks within each session.

[8] Background measures were normalized using the var function in R, and the models used a gaussian distribution. For attention models, depending on the type of data, either gamma (for timing response variables), zero-inflated negative binomial, or gaussian distributions were used.

[9] Preliminary analyses for collinearity showed that family immigrant status had a moderate negative correlation with parent education level (r=-0.396, p<.001). Additionally, a significant relationship was found between school category (state, semi-private, private) and English exposure at school ($F(2,459)=774.4$, p<.001), indicating that much of the variability in English exposure is influenced by school category. Given these findings, both family immigrant status and school category were excluded from further analyses to prevent multicollinearity.

[10] Two measures of English exposure are used to present the results. The amount of 'English exposure at school' (expressed in percentages) was used for detailed GLMM analyses to capture nuanced and granular exposure levels, particularly within the bilingual schools, which varied across six levels. For descriptive data in tables, the categorical variable ('type of school') was employed to succinctly summarize the results across the different educational contexts (non-bilingual, bilingual, immersion), enhancing their interpretability.

[11] In all figures displaying interaction plots (Figures 2-5), shaded areas around the lines represent 95% confidence intervals of the predicted values.

[12] For tasks measuring timing, lower scores (and negative coefficients) reveal a better performance; for tasks measuring accuracy, higher scores (and positive coefficients) indicate a better performance.

[13] *CreatureCounting-timing* was analyzed separately with a subset of the participants who performed this task, as only those who scored 3 or more in *CreatureCounting-accuracy* received a timing score. This subset included 14 out of 66 participants from the non-bilingual

schools (21.21%), 64 out of 140 participants from the bilingual schools (45.71%), and 16 out of 25 from the immersion school (64%).

Tables

Table 1. *Number of participants, age range, and age mean (SD) per type of school in T0 and T1*.

	T0			T1		
	N	Age range	Age mean (SD)	N	Age range	Age mean (SD)
Non-bilingual	66 (33 girls)	5.81-6.82	6.35 (0.27)	66 (33 girls)	6.33-7.46	6.68 (0.39)
Bilingual	140 (77 girls)	5.74-6.78	6.28 (0.27)	138 (77 girls)	6.42-7.42	6.63 (0.40)
Immersion	25 (16 girls)	5.88-6.83	6.44 (0.28)	25 (16 girls)	6.43-7.33	7.03 (0.27)

Table 2. *Means (SDs) for age, NVR, WM, L1 vocabulary, and L2 vocabulary per type of school at T0.*

	Non-bilingual	**Bilingual**	**Immersion**
Age	6.34 (0.28)	6.27 (0.27)	6.44 (0.27)
Non-verbal reasoning	21.12 (3.86)	22.65 (4.77)	21.72 (3.61)
Working memory	3.28 (0.51)	3.45 (0.52)	3.68 (0.47)
L1 vocabulary	67.69 (11.50)	74.35 (12.96)	69.00 (11.60)
L2 vocabulary	12.43 (7.70)	21.53 (12.88)	57.44 (10.41)

Table 3. *Means (SDs) for age, NVR, WM, L1 vocabulary, and L2 vocabulary per type of school at T1.*

	Non-bilingual	**Bilingual**	**Immersion**
Age	6.86 (0.39)	6.63 (0.40)	7.03 (0.27)
Non-verbal reasoning	26.39 (4.04)	24.79 (4.33)	28.88 (4.19)
Working memory	4.12 (0.77)	4.44 (0.61)	4.80 (0.57)
L1 vocabulary	81.92 (11.22)	84.28 (13.04)	84.76 (11.80)
L2 vocabulary	22.84 (12.79)	35.82 (17.24)	71.08 (10.19)

Table 4. *Means (SDs) for each attentional/executive measure per type of school at T0.*

	Non-bilingual	**Bilingual**	**Immersion**
SkySearch (timing)	10.5 (5.84)	9.63 (5.53)	7.18 (3.34)
SkySearchDT (timing)	34.6 (43.8)	39.5 (69.9)	22.2 (40.5)
CreatureCounting-accuracy (0-7)	1.01 (1.47)	2.46 (2.21)	3.24 (2.22)
CreatureCounting-timing	7.61 (1.11)	7.82 (2.33)	6.58 (1.19)
Walk/Don'tWalk (accuracy) (0-20)	6.69 (3.04)	9.12 (3.51)	9.80 (3.08)
OppositeWorlds-congruent (timing)	45.00 (9.80)	40.74 (8.91)	34.72 (6.05)
OppositeWorlds-incongruent (timing)	57.00 (14.46)	51.00 (10.95)	45.56 (12.16)

Table 5. *Means (SDs) for each attentional/executive measure per type of school at T1.*

	Non-bilingual	**Bilingual**	**Immersion**
SkySearch (timing)	8.34 (3.51)	6.95 (2.60)	5.96 (2.64)
SkySearchDT (timing)	56.12 (7.60)	57.46 (11.86)	56.44 (6.76)
CreatureCounting-accuracy (0-7)	3.16 (1.68)	3.76 (1.63)	4.48 (1.29)
CreatureCounting-timing	6.59 (1.61)	6.18 (1.51)	5.65 (0.97)
Walk/Don'tWalk (accuracy) (0-20)	8.07 (3.79)	10.03 (3.44)	11.32 (2.74)
OppositeWorlds-congruent (timing)	35.12 (6.98)	32.44 (6.10)	28.76 (5.53)
OppositeWorlds-incongruent (timing)	45.16 (11.95)	42.90 (8.70)	37.60 (8.48)

Figures

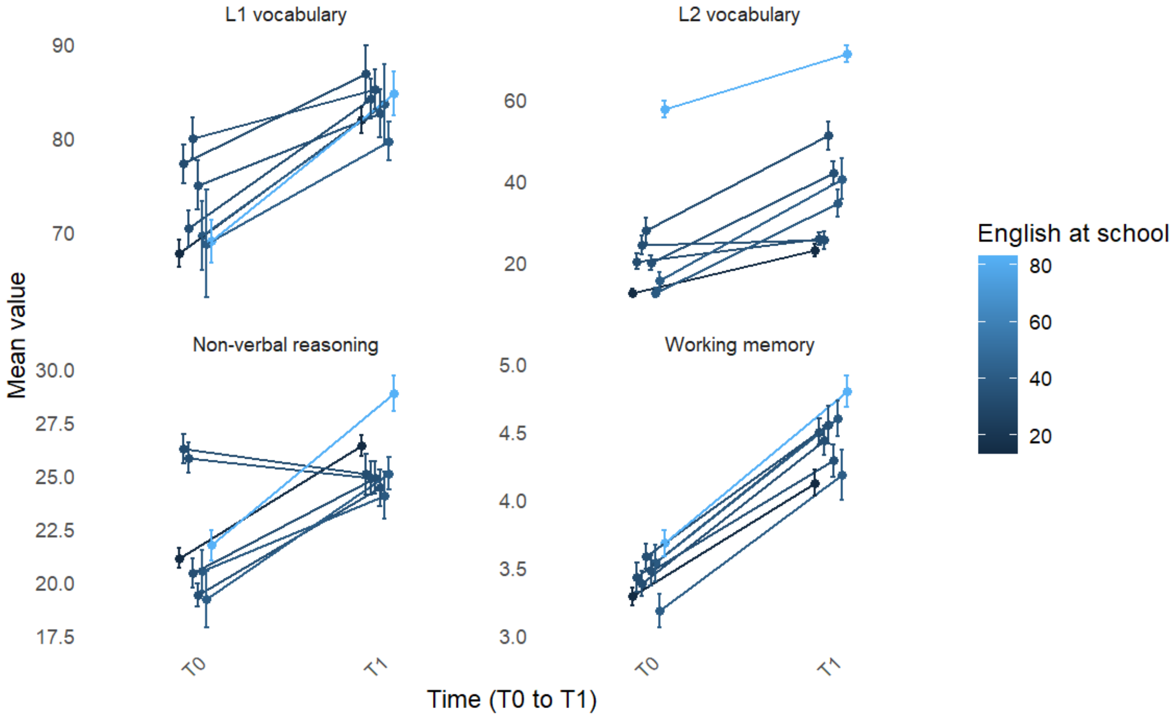

Figure 1. Improvement in background measures from T0 to T1 by groups. Note: dots represent mean values, error bars indicate standard errors of the means, and lines show the progression over time.

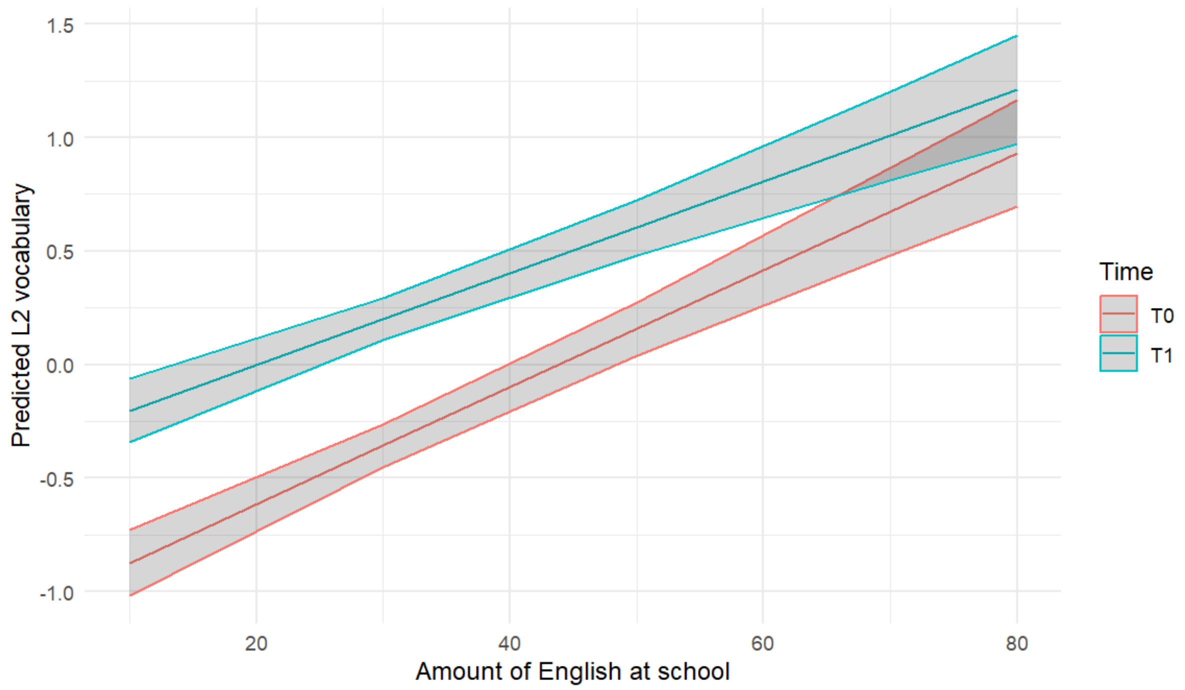

Figure 2. Interaction effect between English at school and time on L2 vocabulary.

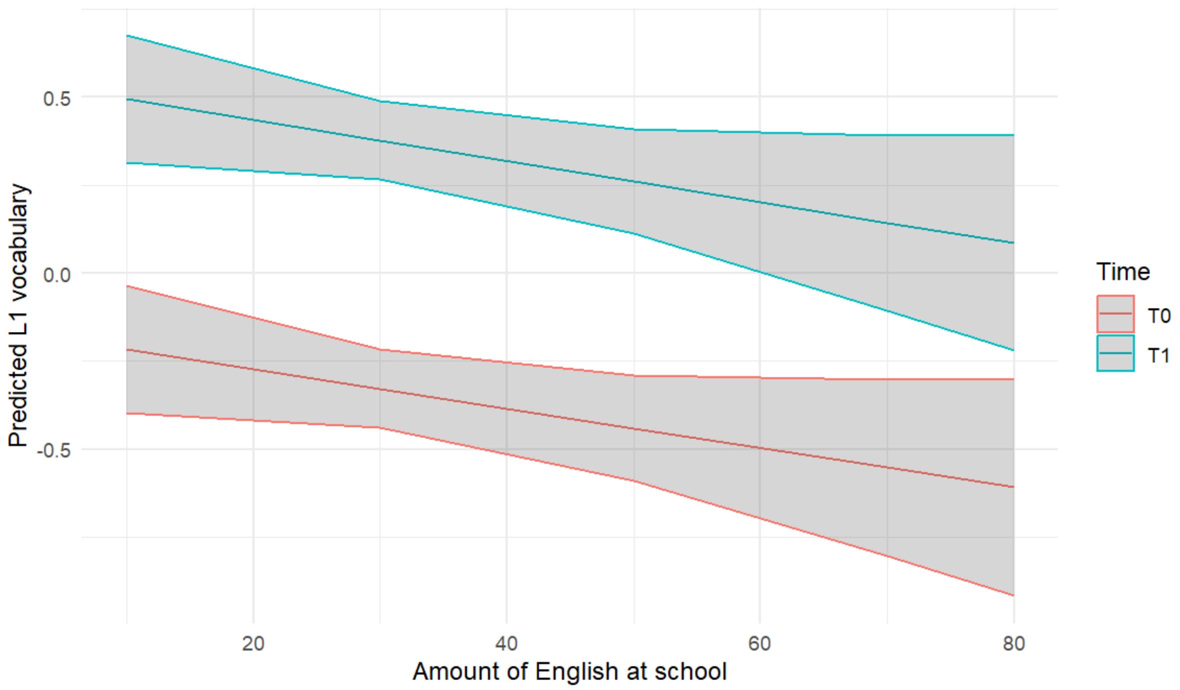

Figure 3. Interaction effect between English at school and time on L1 vocabulary.

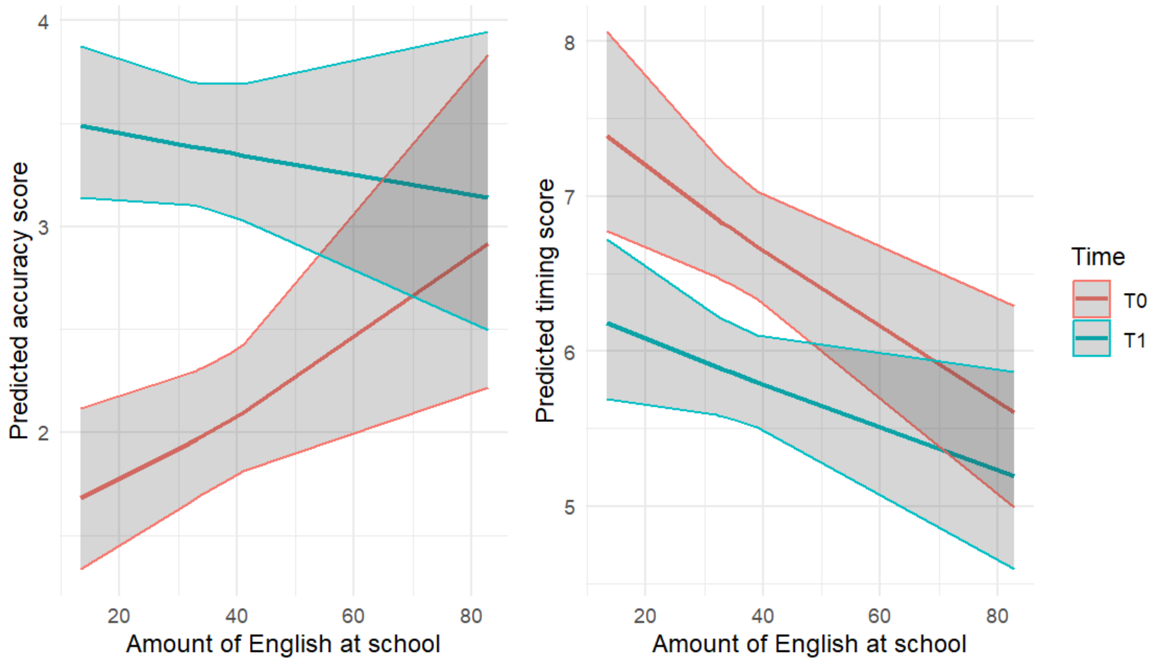

Figure 4. Interaction effect between English at school and time on *CreatureCounting-accuracy* (left) and *CreatureCounting-timing* (right).

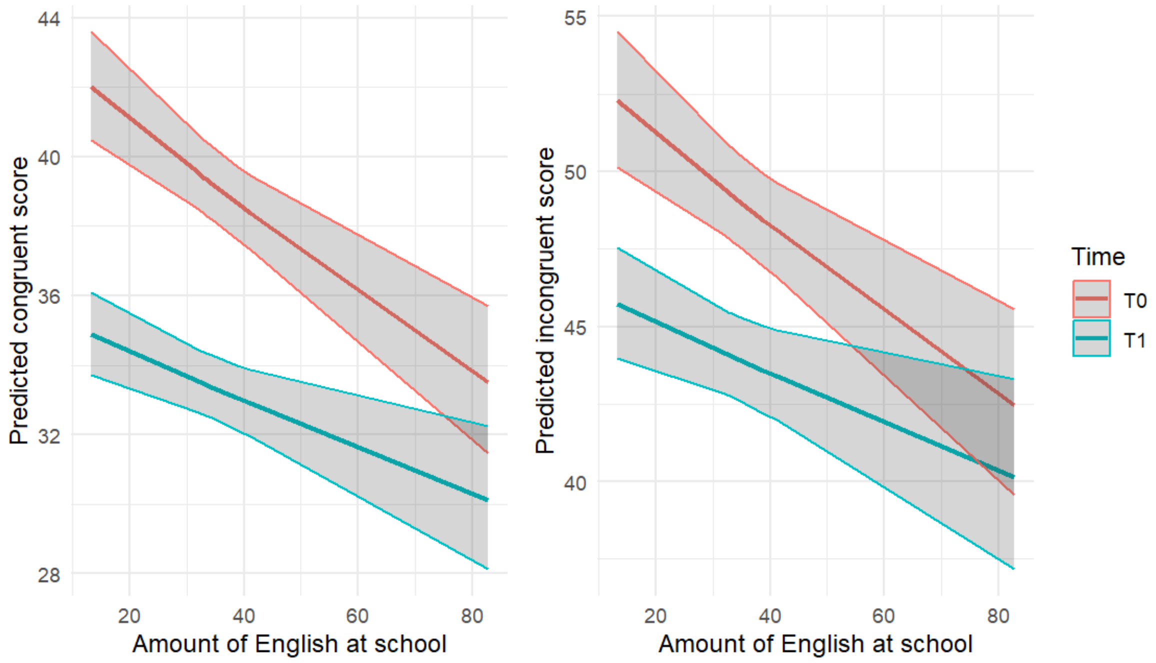

Figure 5. Interaction effect between English at school and time on *OppositeWorlds-congruent* (left) and *OppositeWorlds-incongruent* (right).