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Comparative Study of Executive Functions in Bilingual TD and SLD Children from Grade 2 to Grade 4.

Anna Kechichian, Aurélie Simoës-Perlant, Karine Duvignau

Abstract

The development of executive functions (EF) in bilingual children with a specific learning disorder (SLD) is a growing area of research interest. Our objective is to study the development of EF in Lebanese children with typical development (TD) and presenting SLD, in the primary grades (Grades 2, 3, and 4). Ninety TD and ninety SLD children, in Grade 2, 3, and 4, were recruited in Lebanese public and private schools. Inhibition, working memory (WM), flexibility and planning were evaluated through the following tests: Image matching test, Numbers retention test in backward order, Corsi block tapping test, Opposite Worlds test, Categorization test (Animal Sorting), and LABY 5-12 test. When comparing the two groups of children in terms of inhibition and WM, the statistical tests show significantly that SLD children are more impulsive than TD children and have a lower visuospatial and verbal WM. SLD children are also slower than TD children in the Opposite Worlds test that assesses flexibility. Similarly, the planning capacity is lower in SLD children compared to TD children. All results improved across grades. This work can explain the cognitive components related to learning, for a better management of specific learning disorders.

Keywords: Executive Functions, Primary Grades, Typical Development, Specific Learning disorders.

Introduction

Executive functions (EF) refer to the capacities of regulation of mental functions allowing the subject to adapt to new situations, to develop strategies, to make choices or to make decisions, all in an automated way (Korkman, 2000). The four main executive components are: inhibition, working memory (WM), flexibility and planning (Diamond, 2013). These cognitive processes develop gradually from the first months of life until adolescence, influencing the child's educational achievements, and an injury at a critical period of brain development risks disrupting the underlying emerging skills as well as their subsequent development (Dennis, 2006). According to the "Executive functions and related terms" developmental model of Diamond (2013), inhibitory control and WM would be the precursors of the following development of flexibility and then of higher-level EF such as planning. Indeed, these EF (inhibition, WM, flexibility, and planning) are linked to the development of the prefrontal regions (Roy, Gillet, Lenoir, Roulin, & Le Gall, 2005). Their maturation occurs at a later point in a child's development compared to other cortical regions and continues until early adulthood (Steinberg, 2005). The neuropsychological disorders observed in various acquired or developmental pathologies evoke the notion of "dysexecutive syndrome", affecting both the cognitive and behavioral spheres (Andrès, 2004). At the cognitive level, in accordance with the recent model of executive development, disturbances can concern the different "cold" components (cognitive components) of EF, sometimes causing severe learning disabilities (Roy, 2015). Several tools from adult neuropsychology have been adapted and implemented with children for the evaluation of executive functioning. These tasks are based on standardized materials and procedures. Both reaction times and response accuracy are considered in evaluating children's performance on different measures of EF. One of the obstacles encountered in evaluating EF is the lack of clarity regarding the involvement of different executive processes within the same task (Grefex, 2008).

Several studies have reflected the advantages of bilingualism on cognitive capacities, focusing on the performance of bilingual children in terms of oral language and executive functions tests (Bialystok, 2010; 2011; Laloi, 2015; Poulin-Dubois, Blaye, Coutya, & Bialystok,

2011). However, other studies did not show significant differences between bilingual and monolingual children for most executive functions (Abdelgafar & Moawad, 2015; Arizmendi, Alt, Gray, Hogan, Green, and Cowan, 2018) and on nonlinguistic inhibitory control processes (Hilchey & Klein, 2011). Paap and Greenberg (2013) expressed that there is no coherent evidence for a bilingual advantage in executive processing: the result of a specific executive process in one task frequently does not predict the result of a related task. Jalali-Moghadam and Kormi-Nouri (2015) suggest that bilingualism may be a difficulty in the case of children with learning disabilities. According to the DSM-5 (Diagnostic and Statistical Manual of Mental Disorders, 2013), the term “specific learning disorders” (SLD) has become more widely used in the literature (instead of dyslexia), collecting all the disorders (regardless of their type and degree of severity). Three sub-components of reading disorder are differentiated: word reading accuracy, speed and reading comprehension. Regarding writing production, factors such as the precision of spelling and grammar, punctuation, clarity and organization of written expression are taken into account. Administrative thresholds were determined to demonstrate the severity of the disorder, ranging from -1 Standard Deviation (SD) to -2.5 SD (depending on the tests used).

Anatomy and brain activation studies carried out from the 1980s to the present attempt to identify the biological causes of SLD. Cortical and subcortical structural anomalies have been highlighted (Galaburda & Livingstone, 1993; Giraldo-Chica & Schneider, 2018). Apart from the theory that relates to a phonological deficit (Kovelman et al., 2012), another highlights a visual-attention deficit in SLD children relating to a dysfunction of the magnocellular pathway of the lateral geniculate nucleus (linked to the visual system) (Abu Rabia & Taha, 2006; Bosse, Tainturier, & Valdois, 2007; Landerl et al., 2013; Valdois, 1996). Studies by Reiter, Yucha and Lange (2005) and Alahmadi (2017) have shown that SLD children were slower in processing visual information and weaker than TD children in conditions of inhibition. According to Alahmadi (2017), this is probably the consequence of delayed maturation of the frontal cortex. Majerus and Cowan (2016) add that an impairment of short-term memory of series is frequently reported in SLD children. This alteration occurred for the retention of verbal and visual-spatial sequence information. According to Valdois et al. (2003) and Boden and Giaschi (2007), the magnocellular disorder leads to a deficit in visual treatments, a memory problem, and therefore a written language impairment. Altemeier, Abbott and Berninger (2008) have also reported a dysfunction on mental flexibility and organizational tasks in SLD children in primary grades.

The disorders that arise from these different explanatory theories can be grouped under the spectrum of EF deficits. In this context, disorders in terms of attention, inhibition, WM, flexibility and planning have been reported in SLD children, whether or not diagnosed with behavioral disorder (Swanson & Ashbaker, 2000; Kallitsoglou, 2018). When there is a deficit in reading or spelling, it is marked in both languages (that involve an alphabet) for bilingual children (Valdois, Peyrin, Lassus-Sangosse, Lallier, Demonet, & Kandel, 2014).

In a multilingual country like Lebanon, the learning of oral and written language is done in several languages. In Lebanon, French and English are taught in the majority of schools and are the languages used in different subjects such as science and mathematics, in addition to Arabic which is the official language of the country. The Lebanese constitution provides the teaching of at least one of these two foreign languages alongside Arabic, following decrees dating back to 1926. According to the latest version of the Ministry of National Education programs (1997), children are exposed to a second language (L2) from kindergarten, throughout schooling. This L2 is the language of learning for linguistic (oral and written language), scientific (mathematics, physics, chemistry, etc.) and sometimes cultural subjects. Whereas the L2 is employed as the medium of instruction for three-quarters of the school day, the remainder is conducted in Arabic and is mainly devoted to linguistic and cultural matters (history, geography, civil education, etc.). These Lebanese educational programs were adopted since the historic introduction of Francophone education in Lebanon in the 1970s, with the creation of the Francophonie International Organization (FIO). Lebanese schools had to follow the FIO program to grant the French Baccalaureate and have Lebanese diplomas recognized in other member countries.

Bilingualism then forms an important factor in the Lebanese education system. The child is therefore exposed early to different writing systems requiring on his/her part a cognitive effort (in attention, memorization etc.) so that s/he can adapt to the specificities of each language. French is considered an opaque language, given the complexity of its orthographic system: specifically the presence of digraphs and trigraphs, lexical irregularities, homonyms and homophones, and plural rules (Catach, 1995). The Arabic orthographic system is more transparent and is mainly based on the principle of phoneme-grapheme conversion (Kouloughli, 1994). The writing is done from right to left and requires several shapes for each letter depending

on their positions in the word. Arabic letters are visually differentiated by the number and position of dots, and audibly differentiated by silent and sonorous sounds as well as emphatic and non-emphatic sounds. Certain spelling elements linked in part to grammatical rules are however a "source of opacity" in the Arabic language (Saiegh-Haddad, & Henkin-Roitfarb, 2014): namely, the rules of "alif" and "hamza" within words, the rules of nunation and that of the /t/ letter at the end of words. The stages of acquiring the different spelling rules start mainly from Grade 2 class in the Lebanese school curricula.

In this context, the observations of a typical bilingual child or one presenting specific learning disorders remain limited. Furthermore, the difficulties or disorders that may be encountered during development, especially in primary grades, are not systematically linked to these cognitive aspects (in monolingual children as in bilingual children). Our objective is then to study in a cross-sectional way: the development of EF in bilingual (Arabic-French) Lebanese TD and SLD children, in the primary grades (Grades 2, 3 and 4). We assume that performance at all EF evolves more efficiently in TD children than in SLD children, from class to class. We selected these investigations specifically with these three classes, because between Grade 2 and Grade 4, according to the Lebanese school curricula (1997), the child begins to consolidate basic learning.

Methods

Participants

Our sample consisted of 180 bilingual Lebanese TD and SLD Lebanese children between 8 and 12 years old. To control natural maturation, age would have to be included in our analyses as a covariate. However, we chose to analyze the children's performances according to their grade, as age is not always correlated with grade level. They were recruited from Grades 2, 3 and 4 classrooms in ordinary, private and public schools and are distributed as presented in Table 1.

We have 30 TD children and 30 SLD children, so 60 children per grade, with an average age of 7 years 11 months ($SD = 6$ months) in Grade 2, 8 years 10 months ($SD = 6$ months) in Grade 3, and 9 years 11 months ($SD = 5$ months) in Grade 4. The enrollment of children from public schools in our study is lower than that of private schools. This is because we tried to

harmonize the total sample by controlling the socio-cultural environment. The presence of Syrian children (monolingual or coming from a different socio-cultural background that may affect learning) was also dominant in public schools. Consequently, the selection of children meeting our inclusion and exclusion criteria in this context was more difficult and limited. 7 Arabic-French speaking private schools and 7 Arabic-French speaking public schools from different regions of Beirut were contacted after the approval of the Ministry of National Education Ethics Committee.

Contact was made with the coordinators of the grade levels (Grades 2, 3 and 4) to select the TD and SLD children according to specific criteria. The general inclusion criteria were: (1) bilingual Arabic and French children of Lebanese parents who had lived in Lebanon for at least three years (to be sure that children are following the Lebanese educational curricula); (2) children with no auditory or visual sensory disturbance (visual correction by glasses is accepted); (3) children with normal IQ. The general exclusion criteria were: (1) children who had unsuitable schooling (irregular schooling) or in a socio-cultural environment not favorable to learning (poor stimulation); (2) children with oral language disorders; (3) children with hyperactivity or behavioral problems. The inclusion criteria specific to TD children were: (1) children with normal development of learning; (2) no speech, psychomotor or psychological remediation reported; (3) normal schooling, without grade repeating. The inclusion criteria specific to SLD children were: (1) children with mild or moderate reading and spelling disorders in first language (L1) and L2, diagnosed by neuropsychologists or speech and language therapists according to DSM-5 (2013); (2) speech, psychomotor or psychological remediation reported from the primary grades; (3) repeating a grade or specialized schooling (children benefiting from an inclusion program or an individualized and adapted program); (4) children not taking medication (e.g., methylphenidate, atomoxetine, carbamazepine); (5) children without neurological disorders (e.g., epilepsy, dyspraxia).

Following recruitment, we learned from the educators the L1/dominant language of each child: They have reported the most used language at school and with friends and asked the parents about the most used language at home and in extracurricular activities. In Table 2, we present the distribution of participants according to their L1 (Arabic / French). The L1 for all

participants in public schools is Arabic. In private schools, 134 participants noted Arabic as their L1 whereas 46 participants listed French as L1.

Procedure

The participants were tested individually in a quiet room during school hours in coordination with the main teachers. The total duration of the test was approximately 1 hour 45 minutes carried out over two sessions and interspersed with breaks depending on the pace of each child.

As a first step, the Raven Progressive Matrix test (Raven, 1991) was used to control cognitive level. Matrices are theoretically correlated to a high IQ in the WISC test (Wechsler Intelligence Scale for Children, Wechsler, 2014). The ELO-L test (Evaluation of Oral Language in Lebanese children, Zebib, Henry, Khomsi, Messarra, & Kouba Hreich, 2017) was also administered to eliminate a language deficit. We note that the ELO-L calibration is only valid up to the age of 8 and corresponds to the ages of Grade 2 children in Lebanon. Whereas for children of Grades 3 and 4, we had no benchmark test on the Lebanese bilingual population in terms of oral language. However, there are French tests that target this age group (e.g., EXALang 8-11, Thibault, Lefant, & Helloin, 2012), but these tests cannot be used with Lebanese children in public schools because they are Arabic speakers. In speech therapy, data processing is done in this case qualitatively: the accurate repetition of words or non-words (long and complex ones) and the construction of complex sentences are two important clues that eliminate a specific language impairment, regardless of the children age (Jakubowicz & Tuller, 2008). As a result, we opted for qualitative evaluation using ELO-L with all the children of Grades 2, 3 and 4 to exclude participants with a specific language impairment. For children in difficulty, we have also consulted their previous assessments which already reflect the presence or absence of oral language disorders during the development stages (through the anamnesis and the assessments results). For the three grade levels, the children who are clearly in difficulty relative to their peers (in the various subtests, especially in terms of speech articulation and syntactic expression), were

excluded from the study and considered as having a language impairment. In our final sample, according to the inclusion and exclusion criteria related to oral language skills, all the children obtained scores: greater than or equal to 31/34 in the reception lexicon, greater than or equal to 24/27 in the oral comprehension, greater than or equal to 63/70 in the production lexicon, greater than or equal to 28/37 in the production of statements and lastly greater than or equal to 27/28 in the repetition of words.

In a second step, we administered the different EF tests to all subjects randomly by timing them. The order of the assessment was noted for each subject.

Methodology

In our protocol, we have selected certain tests to have a global view on the main EF components. The EF tests were administered in the children's L1, and they are presented below.

(1) To assess inhibition, we used the image matching test "Test d'appariement d'images" (Marquet-Doléac, Albaret, & Bénesteau, 1999). This test assesses cognitive impulsivity and attention in children from the ages of 7 years 6 months to 14 years 5 months. It consists of 11 boards, the first serving as an example. The drawings of each board are significantly identical, with a reference model at the top. Below, we find 6 copies differing by one detail from the reference, except one drawing that the subject must find. The instructions require the subject to find the perfect copy in one minute maximum and to give the correct answer on the first try. Otherwise the answers will be counted errors until the success or the end of time. For each item, we noted the time of the first response, the time of the exact response and the number of errors.

(2) To measure verbal WM, we used the numbers retention test in backward order, subtest of "ODEDYS" (Jacquier-Roux, Valdois, & Zorman, 2005), calibrated from 2nd to 5th grade. In this test, we give the first sequence of two numbers orally, pronouncing each one well with a space of one second and we ask the child to repeat the sequence heard in reverse order, starting from the end. The responses are noted in the corresponding columns. Reverse span is the number of digits of the longest sequence repeated without errors and in reverse order (e.g., 2 6 7 1 → 1 7 6 2).

(3) To assess visuospatial WM, the "Corsi block tapping test" (Corsi, 1972) was selected in the reverse condition. This test is calibrated on a population of children from Grade 1 to Grade 6 (Fournier & Albaret, 2013). It consists of a board on which are fixed nine cubes or blocks

arranged in an asymmetrical way and numbered on the side visible only by the examiner. He successively touches a certain number of blocks (at the rate of one block per second) in a pre-established order and asks the subject to reproduce the sequence by showing with the finger all the cubes designated, but in reverse order, from the last to the first. This test therefore consists of reproducing, in reverse order, a sequence of pointing movements of different cubes shown by the examiner. The number of blocks increases progressively in order to determine the visuospatial span, which is the maximum number of blocks that the subject recalls in backward order without error.

(4) To assess flexibility, we first selected the Opposite Worlds test “Les mondes contraires”, which is a subtest of TEA-Ch (Manly, Robertson, Anderson, Nimmo-Smith, Lussier, & Flessas, 2006). TEA-Ch measures the different attentional capacities in children from 6 to 13 years old. This subtest specifically measures mental flexibility related to attentional control: the ability to harmoniously change the direction of attention from one object to another. In this subtest, we have two conditions: a control “Same World” condition where the children normally name the figures "1" or "2" as they succeed each other in the boxes on the test book; and a “Reverse World” where they must say "one" when the number "2" appears and "two" when the number "1" appears. Since any error must be corrected by the examiner, the speed with which the children manage to complete the course during the second condition (Reverse World) is a good measure of mental control and cognitive flexibility. A total of four items are presented to the child. We keep the sum of the times for the two items (2 and 3) of the Reverse World (the two items (1 and 4) being linked to the “Same World”).

(5) Flexibility was also evaluated by the Categorization (Animal Sorting) test, subtest of “Nepsy-II” (Korkman, Kirk, & Kemp, 2012). The Nepsy-II is a neuropsychological test, which stands for "A Developmental NEuroPSYchological Assessment". It evaluates children aged between 3 and 4 years and between 5 and 16 years in six different areas: attention and executive functioning, language, memory, learning, social perception, sensorimotor and visuospatial process. The subtest categorization in the “attention and executive functioning” section assesses mental flexibility linked to conceptual reasoning (in children from the ages of 7 to 16): the ability to formulate basic concepts, to carry out an action based on these concepts and to go from one concept to another. This subtest is made up of 8 animal cards with some common criteria (e.g.,

colors, number of animals, common pattern etc.). The child must classify them several times in two piles of four cards, according to his/her own sorting criteria, without giving verbal explanations. The different combinations of cards are noted by the examiner. The timing stops after 6 minutes or when the child expresses that he has finished. We stop the test after 2 minutes if the child does not provide any response. In the end, the total of errors (incorrect combinations or repeated series) as well as the total of correct combinations are noted on the scorecard.

(6) To test planning, we selected the “LABY 5-12” labyrinth test (Marquet-Doléac, Soppelsa, & Albaret, 2010). In the "screening version" (usually used in the systematic examination), a first sequence of labyrinths concerns children from 5 to 7 years old and a second sequence concerns children from 8 to 12 years old. We then selected the second sequence in the assessment of our population. The test is made up of 6 circular labyrinths. An example was given at the start. Circular labyrinths bring an additional level of difficulty. They impose continuous observation and attention to maintain the resolution strategy, unlike the angular shape that more easily allows visual jumps without affecting the whole monitoring. We asked the child to trace the path from the start to the finish (showing each location). We explained to him that if he was wrong, he can go back to find the right path, but he must not cross the lines. We encouraged him to take the time to look carefully, even if he was timed, to avoid mistakes. Then, during the test, each labyrinth was timed, and the total time was noted (observation and tracing). The total time was used for the calculation of the general error index. During the correction by using the corresponding test's transparencies, the different errors were measured: specifically, the wrong directions, the additional distances, and the lines cut.

EF Tests Criteria and Rating

First, to evaluate the inhibition, we used the Impulsivity Index (related to the image matching test) obtained from $\frac{\text{Number of errors} \times 60}{\text{Total Time}}$.

Second, to assess the verbal WM, we noted the span of the longest numbers sequence repeated without errors and in reverse order. Similarly, to assess the visuospatial WM, we noted the maximum number of Corsi blocks that the subject recalls in backward order without any error.

Third, to assess flexibility in the Opposite Worlds test, we took into account the total time of the “Reverse Worlds” in seconds. While for the categorization test, we considered the total number of correct categories of four cards completed by the child.

Lastly, to evaluate the planning, we have retained the General Errors Index (related to LABY 5-12 test) from:
$$\frac{\text{lignes cut+bad directions}+\left(\frac{\text{additional distance}}{10}\right)}{\text{Total labrinths time}} \times 60.$$

Following the presentation of the EF criteria that will be studied in our experimental protocol, we move on to the results.

Results

In this study, we treated the results obtained in the EF tests on the statistical software SPSS for Windows (Chicago, IL, USA, version 25.0). The significance level used corresponds to $p \leq 0.05$. First, the initial comparability between the two groups TD and SLD was carried out regarding age, sex, nature of the school and primary language. The Chi-square tests were used for the comparison of the percentages and the student's test for the comparison of the means. The results of the EF will be presented subsequently, using the following judgment criteria: the Impulsivity Index (obtained from the image matching test) to assess the inhibition; the scores obtained on the Corsi test and the reverse numbers retention to assess the visuospatial and verbal WM; the total time of “Reverse Worlds” (obtained in the Opposite Worlds test) and the total of correct answers (obtained in the categorization test) to assess the flexibility; as well as the General Errors Index (obtained from the Laby 5-12 test) to assess planning. The means and standard deviations were used to describe these quantitative variables.

Kolmogorov-Smirnov tests were performed to assess the normality distribution of continuous variables. Levene's tests were conducted to assess the equality of variances.

Parametric tests were used when the assumption of normality distribution and the equality of variances are met, otherwise non-parametric tests were applied.

Two-way analysis of variance followed by univariate analysis and Bonferroni multiple comparison tests were applied to compare each of the following variables: impulsivity index (Table 4); Corsi (Table 5); reverse numbers retention (Table 5); correct responses in

categorization (Table 7); and General Errors Index (Table 8) according to factors of grade-levels (Grades 2, 3, 4) and participants (TD/SLD).

As for the variable total time of Reverse Worlds (Table 6), non-parametric tests were used; Kruskal Wallis test was applied to compare the total time among Grades 2, 3, and 4, and Mann-Whitney was used to compare between TD and SLD.

Comparability Between the Two Groups of Children TD and SLD

The comparability between the two groups TD and SLD is presented in Table 3.

One hundred and eighty children including 90 TD and 90 SLD were involved in this cross-sectional study. The average age ($p = .295$), the type of school ($p = .876$) and the primary language ($p = .733$) are not significantly different between TD children and those with SLD. However, a larger number of boys were present in the SLD group ($p = .011$). This significant disproportion between the sexes is universally recognized with sex ratios of 1:3 (1 girl for 3 boys) on average (Habib, 2018). This indicates that the two groups of TD and SLD children are comparable in terms of age, type of school and primary language.

Comparisons: Impulsivity Index

The means and standard deviations of the Impulsivity Index evaluating the inhibition in TD and SLD children according to grade are presented in Table 4.

When comparing TD and SLD children, the Impulsivity Index is significantly larger for SLD children in Grade 2 ($p = .017$) and Grade 3 ($p = .001$), but the difference is not significant for Grade 4 ($p = .144$).

F statistics for the comparison between TD and SLD participants = 17.143, $df = 1$, p -value < 0.001.

In terms of the inter-grade comparison of TD children, the Impulsivity Index is significantly different between grade levels ($p = .033$); it is high for Grade 2, but the difference is not significant between Grade 3 and Grade 4 ($p = 1.000$).

In SLD children, the Impulsivity Index is significantly different between grade levels ($p = .017$); it is higher in Grade 2, intermediate in Grade 3 and lower in Grade 4.

F statistics for the comparison between grades = 6.813, $df = 2$, $-p\text{-value} = 0.001$.

Comparisons: Corsi and Reverse Numbers Retention

The means and standard deviations of the scores obtained on the Corsi test (in backward order) and the Reverse Numbers Retention test in TD and SLD children according to grade are illustrated in Table 5.

When comparing TD and SLD children, the average of the scores obtained on the Corsi test is significantly lower for SLD children in Grade 2 ($p = .025$), Grade 3 ($p = .001$) and Grade 4 ($p = .002$).

F statistics for the comparison between TD and SLD participants = 29.323, $df = 1$, $-p\text{-value} < 0.001$.

Likewise, the average of the scores obtained in the Reverse Numbers Retention test is significantly lower for SLD children in Grade 3 ($p = .003$) and Grade 4 ($p = .050$), but the difference is not significant for Grade 2 ($p = .473$).

F statistics for the comparison between TD and SLD participants = 11.023, $df = 1$, $-p\text{-value} = 0.001$.

In terms of the inter-grade comparison of TD children, the average of the scores obtained on the Corsi test is significantly different between grades ($p = .019$): specifically, it is lower in Grade 2, intermediate in Grade 3 and higher in Grade 4.

Among SLD children, the mean scores obtained on the Corsi test are significantly different between grades ($p = .039$): notably, it is higher in Grade 4, but the difference is not significant between Grade 2 and Grade 3 ($p = .834$).

F statistics for the comparison between grades = 7.394, $df = 2$, $-p\text{-value} = 0.001$.

With respect to TD children, the mean scores obtained on the Reverse Numbers Retention test are significantly different between grade levels ($p = .001$): specifically, it is lower in Grade 2, but the difference was not significant between Grade 3 and Grade 4 ($p = .323$).

As for SLD children, the mean of the scores obtained in the Reverse Numbers Retention test is significantly different between grade levels ($p = .006$): it is high in Grade 4, but the difference is not significant between Grade 2 and Grade 3 ($p = 1.000$).

F statistics for the comparison between grades = 12.498, $df = 2$, $-p\text{-value} < 0.001$.

Comparisons: Reverse Worlds

The means and standard deviations of the total time variable of the “Reverse Worlds” in TD and SLD children by grade are described in Table 6.

When comparing the TD and SLD children, the total time variable of the “Reverse Worlds” test is significantly longer for SLD children in Grade 2 (MW-U = 11.848, $df = 1$, $p = .001$), Grade 3 (MW-U = 9.313, $df = 1$, $p = .002$) and Grade 4 (MW-U = 4.272, $df = 1$, $p = .039$).

In terms of inter-grade comparison of TD children, the total time variable of “Reverse Worlds” test is significantly different across grade levels (K-W = 15.698, $df = 2$, $p = .001$): notably, the total time is longer in Grade 2 (higher average), intermediate in Grade 3 and shorter in Grade 4 (lower average).

With respect to SLD children, the total time it took participants to complete the “Reverse Worlds” test is significantly different between grades (K-W = 25.523, $df = 2$, $p = .001$): the total time is longer in Grade 2 (higher average), but the difference is not significant between Grade 3 and Grade 4 (K-W = 25.523, $df = 2$, $p = .138$).

Comparisons: Categorization (Animal Sorting)

The means and standard deviations of the total number of correct answers in the categorization test for TD and SLD children by grade are described in Table 7.

When comparing TD and SLD children, the total of correct answers is not significantly different between the two groups of children in Grade 2 ($p = .396$) and Grade 4 ($p = .699$). However, it is greater for TD children in Grade 3 ($p = .005$).

F statistics for the comparison between TD and SLD participants = 5.612, $df = 1$, -p-value = 0.019.

In terms of the inter-grade comparison of TD children, the total of correct answers is significantly different across grades ($p = .026$): the average is lower in Grade 2, but the difference is not significant between Grade 3 and Grade 4 ($p = 1.000$).

Among SLD children, the total of correct answers is significantly different between grades ($p = .047$), as the average is lower in Grade 2, intermediate in Grade 3 and higher in Grade 4.

F statistics for the comparison between grades = 5.091, $df = 2$, -p-value = 0.007.

Comparisons: General Errors Index

The means and standard deviations of the General Errors Index for TD and SLD children by grade are shown in Table 8.

When comparing TD and SLD children, the General Errors Index is significantly high for SLD children in Grade 2 ($p = .001$) and Grade 3 ($p = .022$). However, it was not significantly different for Grade 4 children ($p = .417$).

F statistics for the comparison between TD and SLD participants = 14.786, $df = 1$, -p-value < 0.001.

With respect to the inter-grade comparison of TD children, the General Errors Index is not significantly different across grades ($p = .767$). For SLD children, the General Errors Index is significantly different among grade levels ($p = .006$): notably, it is higher in Grade 2, intermediate in Grade 3 and lower in Grade 4.

F statistics for the comparison between grades = 3.673, $df = 2$, -p-value = 0.027.

Discussion

Executive functions are cognitive processes necessary to control and regulate thoughts and actions. In Lebanon, the bilingual context appears to have an influence on executive functioning among school-aged children. It is in this perspective that our study aims to explore the development of EF in 90 TD bilingual Lebanese children and 90 other presenting SLD in Grades 2, 3 and 4. These children were matched by age, type of school and primary language. The evaluation of EF remains debated (Grefex, 2008) because of the involvement of different executive processes within the same task. For example, in Corsi's test (Corsi, 1972) that evaluates the visuospatial WM, the recall of the different locations of the blocks which constitute the sequence (spatial dimension) and the order in which they appear (temporal dimension) require different executive resources. This test exploits one of the mechanisms of the WM, which is itself linked to the updating function (Van der Linden, Hupet, & Feyereisen, 2010). Rudkin, Pearson and Logie (2007) add that Corsi test requires more attentional functions in the "backward order" than in the "forward order" (in cubes pointing). These variables drove us to limit the evaluation of EF to a few tests in our study. The inhibition was evaluated by the image matching test (Marquet-Doléac et al., 1999) and the WM by the Corsi test (Corsi, 1972) in visuospatial mode and by the classic Reverse Numbers Retention test in verbal mode (Jacquier-Roux et al., 2005). Flexibility skills were assessed in both "Reverse Worlds" test (Manly et al., 2006) and categorization animal sorting test (Korkman et al., 2012). The planning skills were assessed using the labyrinths from the Laby 5-12 test (Marquet-Doléac et al., 2010).

When comparing the two groups of children in terms of inhibition and WM, the statistical tests show with significant effects that SLD children are more impulsive than TD children, especially in Grade 2 and Grade 3 and have a lower visuospatial and verbal WM. These results agree with the literature which shows that younger children are more impulsive and the most significant developmental progress would be observed from the age of 9 years old (Romine & Reynolds, 2005). Studies by Reiter, Yucha and Lange (2005) and Alahmadi (2017) have also

shown that SLD children were slower in processing visual information and weaker than TD children in conditions of inhibition. According to Alahmadi (2017), this is probably the consequence of delayed maturation of the frontal cortex. Our results also agree with those of Majerus and Cowan (2016) who add that an impairment of short-term memory of series is frequently reported in SLD children. This alteration occurred for the retention of verbal and visual-spatial sequence information.

The deficits noted in SLD children for inhibition, evaluated through a visual attention test (image matching test), and for visuospatial WM (Corsi test) could also remind us of the magnocellular deficit that has been mainly described through the studies of Galaburda cited by Robichon (1996) then in the research of Giraldo-Chica and Schneider (2018). These authors highlighted hemispherical differences between TD and SLD subjects in the lateral geniculate nucleus, which is linked to the visual system. According to Valdois et al. (2003) and Boden and Giaschi (2007), the magnocellular disorder leads to a deficit in low-level visual treatments (i.e., visual persistence, sensitivity to contrasts, perception of movement), a partial processing of the visual sequence, a memory problem, a reduction in the object to be treated and therefore a written language impairment. These deficits observed in our study can also be explained by the theory of Bosse et al. (2007), that highlighted in SLD children a visual-attentional dysfunction due to slowed attentional displacement, visual-attentional span deficit and perceptual congestion. For Lobier, Zoubrinetzky and Valdois (2012), the visual-attentional deficit is highlighted for verbal material (letters) and also extends to non-verbal tasks (forms), meeting the specificities of our tests. We note that there is no difference between TD and SLD children on visuospatial WM for Grade 2 as both groups essentially recalled nearly the same number of digits backward. A maximum backward span of 3 digits is considered average for the same age range. Moreover, Ratiu and Azuma (2015), did not find a bilingual advantage on this task.

Concerning the poor results of SLD children obtained for verbal WM, the causes can be linked to the increased size of the temporal lobe which has been described by Galaburda et al. (1985) (cited by Valdois, Gérard, Vanault, & Dugas, 1995) or the dysfunction in the language networks of the left hemisphere (Peterson & Pennington, 2015). For these authors, these biological aspects would imply phonological processing deficits as well as weaknesses in information processing speed, which are strongly linked to verbal WM capacities.

Our results also show that SLD children are significantly slower than TD children in the Opposite Worlds test which assesses mental flexibility. We also note a more pronounced success in TD children but without being significant in the categorization test. Similarly, the planning capacity is significantly lower in SLD children compared to TD children, especially in Grade 2 and Grade 3 classes. No performance advantage for 4th graders on the labyrinth test may be due to task difficulty. LABY 5-12 is design based on Porteus Maze test (Porteus, 1950), which has shown significant developmental gains for 6- and 7-year-olds, but ages 8-11 were comparable on performance for all indices according to normative data.

Many other studies described in the literature also support our findings. The studies of Condor, Anderson and Saling (1995) and of Mati-Zissi, Zafiropoulou and Bonoti (1998) have indeed shown a reduction in fluency and categorization capacities and a deficit in planning in SLD children. These studies have also shown weaknesses in logical reasoning and in the adaptation of a cognitive strategy according to changes in the environment. Altemeier, Abbott and Berninger (2008) have reported executive dysfunction on mental flexibility and organizational tasks in SLD children in primary grades. In fact, their performance was significantly lower than in TD children. Finally, in their comparative studies, Helland and Asbjørnsen (2000) and Regrin et al. (2014) showed in SLD children "significant disorders" compared to TD children in terms of visual and hearing attention, inhibitory control, WM, flexibility and the use of strategies. For these authors, such difficulties are part of the SLD and accompany the central deficit of the phonological component of language.

However, we note that the results of the SLD children in our study are similar to those of the TD children in Grade 4, for the various cognitive tests. This could be explained by the fact that SLD children are mainly treated from early grades (Grade 1 or Grade 2) by therapists (speech therapists and/or psychomotor therapists) who theoretically rehabilitate the prerequisites in written language and/or the cognitive aspects besides reading and spelling; and arrived in Grade 4, these children begin to show progress in EF tasks. We can also assume that being bilingual can serve to minimize the impact of SLD on executive functions development.

After comparing the capacities of TD children with those of SLD, the developmental aspect of these four executive components was also observed in the two groups of children through the inter-grade comparisons.

If we observe the results of all the assessments by taking the two groups at the two extremes (Grade 2/Grade 4), we note significant effects regarding inter-grade progression. All results improved across grades, even if the TD children generally exceed the SLD children in the various tests. In terms of specific results, Grade 4 participants significantly outperformed Grade 3 participants, and Grade 3 participants performed better than their Grade 2 counterparts. These intergrade improvements were noted in a variety of areas: particularly, impulsivity decreased; WM remained more effective in both visuospatial and verbal modalities; speed, flexibility, and planning skills improved. These results support the developmental theories of EF.

Starting with inhibition, according to Romine and Reynolds (2005), the most significant developmental progress would be observed between 8 and 9 years of age. We also note that the development of WM (visuo-spatial and verbal) is gradual and linear during childhood until the end of adolescence (Best & Miller, 2010). Likewise, flexibility and planning skills would continue to develop alongside the gradual maturation of the brain (Dennis, 2006). The lack of significance across grade levels in the categorization and labyrinths tests in TD children is associated here to performances stagnation. This would certainly agree with the postulate that planning is a high-level cognitive ability (Diamond, 2013) that matures later, especially between adolescence and adulthood. Normative data from the NEPSY-2 (Animal Sorting), for example, shows very little improvement in correct responses between the same age groups.

The increases observed in our inter-grade cohort also stem from the specificity of the bilingual environment in which TD and SLD children are raised. Studies in the literature have indeed reflected the advantages of bilingualism on cognitive abilities, focusing on the performance of bilingual children on executive tests during their development. Our results remind us of those of Morales, Calvo and Bialystok (2013) that reported that bilingual children have better WM, to control and coordinate the two linguistic systems, or those of Bialystok (2010), that expressed that bilingual subjects use more of their inhibition capacity to avoid possible interference of the second language in oral expression. Regarding flexibility and planning capacities, our results call to mind those of Bialystok and Feng (2009) that showed an advantage of bilingual children in the treatment of complex tasks which require flexibility. They suggest that bilinguals may compensate for weaker language competence in vocabulary with their greater executive control to achieve the same or better levels of performance as their

monolingual counterparts. However, our study does not agree with that of Jalali-Moghadam and Kormi-Nouri (2015) who suggested that performance on different executive tests decreased considerably in bilingual SLD children. These authors studied four groups of children from 9 to 12 years old (bilingual dyslexics, monolingual dyslexics, bilingual normal readers, and monolingual normal readers). Their executive functioning has been examined to exploit inhibitory/attentional control, WM, and planning capacity. Their results showed that the speed of performance on the various tests decreased considerably in dyslexic children. This general decrease was more pronounced in bilingual dyslexic children than in their monolingual counterparts. Furthermore, Park, Ellis Weismer, and Kaushanskaya (2018) examined the development of inhibition, updating, and task shifting over time in monolingual and bilingual school-age children (ages 8-12). Their findings indicate that bilingualism may change the developmental rates of some components of EF but not others, and executive performances between bilinguals and monolinguals can only differ at certain developmental time points.

Among the obstacles encountered in our study, we note that of the oral language evaluation through the ELO-L test (Zebib et al., 2017), because it is only validated up to the age of 8 and corresponds only to the ages of the Grade 2 bilingual Lebanese children. Data processing for Grade 3 and Grade 4 children was carried out qualitatively in our experimental protocol to eliminate a language disorder. The degree of exposure to each language is also important to consider through parental questionnaires, in order to establish links and better understand the results obtained.

Finally, at the level of education, the development of EF can be supported and promoted through instruction. It would be possible to adjust with teachers the educational situations in the school programs. Early childhood intervention programs can include learning in small groups using games with rules to follow. Other advice could be suggested in this context such as: segmenting tasks into successive exercises, respecting the child's fatigue or agree on a code to control the impulsivity. Implementing a project of integration at school would depend on the abilities of each child. The strategies adopted may also be related to the interaction between educators and SLD children to help them achieve better results. Among these strategies is to avoid any distracting factor and use mnemonic techniques to facilitate learning, such as a tactile, auditory or visual ones like colors or spaces between written information. Cognitive

rehabilitation must allow the child to acquire more autonomy to succeed at school. Efforts should be valued and rewarded. For this, it is important to guide the parents as well because they will have an important support role on a daily basis. Some tips can help their child get organized, and these include: explain the objectives to be achieved; control the time (by using a chronometer); set up checklists; ensure that homework is marked on the right date; visualize the schedule of each day with clear routines; insist on the usefulness of each task for motivation; carry out short work sequences with regular breaks in a quiet room without distraction by starting with the most important task first. Finally, board games can also be a way to work on all the EF.

In conclusion, executive functioning of bilingual subjects has awakened the interest of researchers to study how children and adults manage two or more language systems at the same time. The challenge was to better understand the nature of the executive functioning of bilingual SLD children, and to specify their development to provide a better treatment. Literature has allowed us to perceive all the complexity that the Lebanese child must face. This complexity is mainly linked to the peculiarities of learning in both languages (French and Arabic) that require from the child a continual cognitive adaptation to support better learning performance.

Continued research in EF helps to better understand the process, mechanisms and neural bases that support the different capacities of children, to develop actions and strategies to support or reinforce their development. It would be interesting to study the link between the four main executive components: inhibition, WM, flexibility and planning, not only at the biological level but also at the developmental level where one can affect the results of the other. Moreover, it would be interesting to test the effect of EF training on reading and spelling performances in SLD children in both languages. Our experimental protocol could also be carried out with older children, of the upper grades to observe the development of the executive components. Finally, we propose to compare our results with those of monolingual children.

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Table 1

Distribution of TD and SLD participants recruited from private and public schools according to grades with the means and standard deviations of the ages.

		Grade 2	Grade 3	Grade 4
Private schools	TD	21	23	15
	SLD	21	19	18
Public schools	TD	9	7	15
	SLD	9	11	12
Total of 180 participants	Total TD	30	30	30
	Total SLD	30	30	30
Ages mean (years : months)	TD and SLD	7 ;11	8 ;10	9 ;11
Standard Deviation (SD) (years : months)	TD and SLD	0 ;6	0 ;6	0 ;5

Table 2

Distribution of participants according to their L1 (Arabic / French).

Grades	Participants	n	L1 Arabic	L1 French
2	TD	30	23	7
	SLD	30	22	8

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3	TD	30	17	13
	SLD	30	21	9
4	TD	30	26	4
	SLD	30	25	5
Total		180	134	46

Table 3

Comparability between the two groups of TD and SLD children.

	TD (n=90)	SLD (n=90)	p
Age	8.72±1.028	8.89±1.179	.295
Sex			
<i>Boys</i>	35(38.9%)	52(57.8%)	.011*
<i>Girls</i>	55(61.1%)	38(42.2%)	
Schools			
<i>Private</i>	59(65.6%)	58(64.4%)	.876
<i>Public</i>	31(34.4%)	32(35.6%)	
Primary Language			
<i>Arabic (Lebanese)</i>	66(73.3%)	68(75.6%)	.733
<i>French</i>	24(26.7%)	22(24.4%)	

Table 4

Impulsivity Index scores in TD and SLD children by grade.

Impulsivity Index	Grade 2	Grade 3	Grade 4	p	F statistics univariates analyses of comparisons between grades	df
TD	1.676±2.301 ^b	0.771 ± 0.655 ^a	0.974±0.737 ^a	.033*	3.479	2
SLD	2.540±1.686 ^b	1.959±1.104 ^{a,b}	1.503±1.155 ^a	.017*	4.173	2
p	.017*	.001*	.144			
F statistics of univariates statistics for the comparison between TD and SLD	5.770	10.893	2.157			
df	1	1	1			

Different Letters indicate a presence of a significant difference between groups based on Bonferroni multiple comparison tests: a is the variable lowest value, b is the variable highest value, and ab represents the value between a and b.

Two-way ANOVA:

F statistics for the comparison between TD and SLD = 17.143; df = 1; -p-value < 0.001.

F statistics for the comparison between grades = 6.813; df = 2; -p-value = 0.001.

Table 5

Corsi scores and Reverse Numbers Retention in TD and SLD children according to grades.

Corsi in	Grade 2	Grade 3	Grade 4	p	F statistics of univariates analyses of the comparisons between grades	df
Backward Order						
TD	3.67±1.213 ^a	4.27±1.202 ^{a,b}	4.60±1.192 ^b	.012*	4.640	2
SLD	3.00±.983 ^a	3.10±1.125 ^a	3.67±1.124 ^b	.039*	3.328	2
p	.025*	.001*	.002*			
F statistics for the comparison between TD and SLD	5.108	15.643	10.011			
df	1	1	1			
Reverse Numbers Retention	Grade 2	Grade 3	Grade 4	p	F statistics univariates analyses of comparisons between grades	df
TD	3.13±0.730 ^a	3.60±0.621 ^b	3.90±0.712 ^b	.001*	8.676	2
SLD	3.00±0.643 ^a	3.03±0.615 ^a	3.53±0.937 ^b	.006*	5.189	2
p	.473	.003*	.050*			
F statistics of univariates statistics for the comparison between TD and SLD	0.517	9.333	3.908			
df	1	1	1			

Different Letters indicate a presence of a significant difference between groups based on Bonferroni multiple comparison tests: a is the variable lowest value, b is the variable highest value, and ab represents the value between a and b.

Two-way ANOVA for Corsi:

F statistics for the comparison between TD and SLD = 29.323; df = 1; -p-value < 0.001.

F statistics for the comparison between grades = 7.394; df = 2; -p-value = 0.001.

Two-way ANOVA for Reverse number retention:

F statistics for the comparison between TD and SLD = 11.023; df = 1; -p-value = 0.001.

F statistics for the comparison between grades = 12.498; df = 2; -p-value < 0.001.

Table 6

Scores of the total time of Reverse Worlds in TD and SLD children according to grades.

Total Time of Reverse Worlds	Grade 2	Grade 3	Grade 4	p	Kruskal-Wallis tests	df
TD	35.77±7.454 ^b	32.40±11.044 ^{a,b}	28.80±4.405 ^a	.001*	15.698	2
SLD	43.57±10.721 ^b	36.50±8.127 ^a	32.17±6.358 ^a	.001*	25.523	2
p	.001*	.002*	.039*			
Mann-Whitney tests	11.848	9.313	4.272			
df	1	1	1			

Different Letters indicate a presence of a significant difference between groups based on Bonferroni multiple comparison tests: a is the variable lowest value, b is the variable highest value, and ab represents the value between a and b.

Table 7

Scores of correct responses in categorization in TD and SLD children according to grades.

Total of correct answers	Grade 2	Grade 3	Grade 4	p	F	of df
TD	2.23±1.851 ^a	3.37±1.542 ^b	3.07±1.946 ^b	.026*	3.720	2
SLD	1.87±1.224 ^a	2.13±1.502 ^{a,b}	2.90±1.826 ^b	.047*	3.105	2
p	.396	.005*	.699			
F of univariates statistics for the comparison between TD and SLD	0.725	8.206	0.150			
df	1	1	1			

Different Letters indicate a presence of a significant difference between groups based on Bonferroni multiple comparison tests: a is the variable lowest value, b is the variable highest value, and ab represents the value between a and b.

Two-way ANOVA for total of correct answers:

F statistics for the comparison between TD and SLD = 5.612; df = 1; -p-value = 0.019.

F statistics for the comparison between grades = 5.091; df = 2; -p-value = 0.007.

Table 8

General Errors Index scores in TD and SLD children by grade.

General Errors Index	Grade 2	Grade 3	Grade 4	p	F statistics	df
TD	4.59±3.116	3.94±2.433	4.13±3.533	.767	0.265	2
SLD	7.86±4.869 ^b	6.07±3.297 ^{a,b}	4.88±3.758 ^a	.006*	5.270	2
p	.001*	.022*	.417			
F statistics of univariates for the comparison between TD and SLD	12.515	5.335	0.661			
df	1	1	1			

Different Letters indicate a presence of a significant difference between groups based on Bonferroni multiple comparison tests: a is the variable lowest value, b is the variable highest value, and ab represents the value between a and b.

Two-way ANOVA for general index errors:

F statistics for the comparison between TD and SLD = 14.786; df = 1; -p-value < 0.001.

F statistics for the comparison between grades = 3.673; df = 2; -p-value = 0.027.