Sapienza Università Editrice

E-ISSN 2724-2943
ISSN 2723-973X

Psychology Hub (2025)
XLII, 2, 57-68

Article info

Submitted: 04 October 2024
Accepted: 24 April 2025
DOI: 10.13133/2724-2943/18645

Developmental Language Disorder and Developmental Neuropsychology: An Exploration of Executive Functions and Motor Coordination in Preschoolers

Paolo Stievano[1,2,*], Davide Apicerni[1], Barbara Trimarco[1], Sergio Melogno[3], Giovanni Valeri[4], and Teresa Gloria Scalisi[5]

[1] Department of Dynamic and Clinical Psychology, and Health Studies, Sapienza University of Rome, Rome, Italy

[2] ASL ROMA 2, Rome, Italy

[3] Faculty of Psychology, "Niccolò Cusano" University of Rome, Rome, Italy

[4] Child & Adolescent Psychiatry, Department of Neuroscience, Bambino Gesù Children's Hospital, Rome, Italy

[5] Department of Psychology of Developmental and Socialization Processes, University of Rome, Rome, Italy

Abstract

Developmental Language Disorder (DLD) presents a significant challenge, affecting language development and other cognitive areas such as motor coordination and executive functions (EF). This study examined the relationship between executive functions (working memory, inhibition, and cognitive flexibility) and motor skills in a sample of 22 preschool children with DLD and a control group of 22 typically developing peers. Using age-appropriate neuropsychological assessments, the results showed that children with DLD exhibit significant deficits in inhibition and cognitive flexibility compared to typically developing peers. Additionally, correlations emerged between cognitive flexibility deficits and lower motor and planning abilities. These findings suggest a deep connection between the development of language, motor skills, and executive functions, highlighting the importance of early interventions to improve outcomes for children with DLD.

Keywords: Developmental Language Disorder (DLD); Executive Functions preschool children; Inhibitory Control set-shifting; Developmental Coordination Disorder (DCD)

*Corresponding author.
Paolo Stievano
Department of Dynamic and Clinical Psychology, and Health Studies, Sapienza University of Rome,
Rome, Italy
E-mail: paolo.stievano@uniroma1.it
(P. Stievano)

Introduction

Developmental Language Disorder

Language disorders in children pose a complex challenge, significantly affecting various aspects of development and daily functioning. Children with these disorders face significant challenges in language development and use, which can lead to difficulties in social interaction, academic performance, and emotional well-being. Early recognition and intervention are crucial, as they can greatly improve outcomes for affected children (Spratt et al., 2012; Archibald, 2024). Developmental Language Disorders (DLD) are prevalent in about 5-8% of preschool-aged children, making them one of the most common developmental disorders (Zhang et al., 2020). Importantly, poor language development in DLD is not due to hearing impairments, neurological damage, or intellectual disability (Leonard, 1998; American Psychiatric Association (2013), and the disorder can manifest in various ways depending on the specific language components affected.

Children with DLD also often experience nonverbal deficits in social cognition, motor coordination, and executive function (Bishop, 2002; Hill, 1998, 2001; Henry et al., 2012; Roello et al., 2015; Ullman & Pierpont, 2005). Verbal abilities are essential for facilitating actions, reflecting on them, and planning future actions (Kray et al., 2006). Complex cognitive processes, including Executive Functions (EF), rely on the internalization of actions (Ardila, 2012). According to Vygotsky (1978, 1987), language is vital not only for communication but also for thinking and supporting complex operations, such as learned motor sequences and self-regulation. Thus, since children with DLD struggle with language, they face challenges in regulating their actions and thoughts. Additionally, untreated speech and language delays can persist in 40-60% of children, leading to further social, behavioral, emotional, and cognitive issues, underscoring the need for early identification and intervention (Kumar, Arya e Agarwal, 2022).

Executive functions (EF)

EF is a collection of complex cognitive processes linked to the prefrontal cortex and associated subcortical systems (Diamond, 2013; Stuss, 1992). EF is essential for an individual's ability to plan, organize, control impulses, shift focus between tasks, and use working memory (Zelazo & Muller, 2002). EF significantly contributes to academic achievement and overall well-being in children and adolescents (Zelazo, Blair & Willoughby, 2016; Berthelsen et al., 2017; Stievano & Scalisi, 2016; Stievano et al., 2016, 2018).

EF begins to emerge in early life, particularly by the end of the first year, and it undergoes significant changes between ages 2 and 5 (Zelazo & Muller, 2002). The widely accepted model of EF proposed by Miyake et al. (2000) highlights the relative independence of three executive processes: updating, inhibition, and shifting, which are foundational for higher-order EF skills, such as planning and problem-solving (Shokrkon & Nicoladis, 2022). While studies on children aged 8-13 support this three-factor model (Lehto et al., 2003), its applicability to younger children remains a topic of debate. Working memory (WM) is the first cognitive ability to develop, becoming functional around 9-12 months of age (Diamond, 1995), and is assessed through tasks such as the A-not-B task. Inhibitory control develops by age three and continues to improve into early adolescence (Shokrkon & Nicoladis, 2022). The development of WM and inhibition is essential for enhancing cognitive flexibility (Garon et al., 2008).

Relationships between language functioning and EF

Children with language disorders often exhibit atypical EF. However, the extent of these deficits is still being determined, as studies comparing children with DLD and Typically Developing (TD) children have shown mixed results.

Pauls and Archibald (2016) performed a meta-analysis on cognitive flexibility (set-shifting) and inhibitory control in children aged 4-14 years and showed significant differences between DLD and TD children on both measures; however, Lukács et al. (2016) considering children aged 8 years found no differences in cognitive flexibility and controversial results for inhibitory control.

Studies on preschool children were limited, but deficits in inhibition, planning, and problem representation have been noted (Bishop & Norbury, 2005; Roello et al., 2015). In Roello et al.'s (2015) study, younger preschoolers with DLD (average age 53.6 months) displayed significant atypicality in EF, particularly in inhibition and cognitive flexibility; older children with DLD (average age 65.4 months) performed better than younger ones, but still showed impairments compared to controls. Marini et al. (2020) reported that children with DLD performed worse on inhibitory tasks and updating. However, Reichenbach (2016) did not find significant group differences in EF scores.

More recently, Niu et al. (2024) conducted a meta-analysis on cognitive flexibility, inhibitory control, and working memory, finding that the results of comparisons between DLD and TD groups depend on the age of the groups and the type of task. Generally, verbal tasks are more effective at discriminating between the two groups than visuospatial tasks. Moreover, preschool children with DLD exhibited lower performance than TD children in visuospatial WM tasks, but in the school-aged subgroup, the difference was non-significant. The authors hypothesize that at preschool age, the elements of EF have yet to undergo complete differentiation, so other EF elements may influence visuospatial WM performance in the specific task. Another interesting result from Niu et al.'s (2024) meta-analysis is that studies that administered the *BRIEF-parent behavioral measurement* to assess the performance of DLD and TD groups in everyday life found that children with DLD markedly underperformed TD children on the three main components of EF. Niu et al. (2024) hypothesize that the difference between neurocognitive and behavioral results depends on the artificial difficulty of neurocognitive tasks.

The literature examined so far shows that deficits in executive function often occur in preschool children with DLD. However, more research is needed to shed more light on the relative contributions of the three core EF components—working memory, inhibition, and shifting—in discriminating between DLD and TD groups. Moreover, in agreement with the results of Niu et al. (2024), tasks specifically constructed for preschool age in terms of difficulty should be used, and WM measures should be independent of the other EF tasks.

Relationships between EF and motor skills

Many studies emphasize the connection between motor skills and EF, highlighting the interplay between brain development and motor abilities (e.g., Diamond, 2000). The theory of embodied cognition posits that cognitive processes, including EF, are rooted in motor development, facilitating cognitive growth through active engagement with the environment (Foglia & Wilson, 2013). The extensive literature review conducted by McClelland and Cameron (2019) demonstrates that EF and visuomotor integration are distinct constructs. However, EF facilitates the acquisition of basic motor routines, enabling cognitive resources to be directed toward more complex tasks. Consequently, EF and motor skills are essential for early learning in children. The authors state that reciprocity and automaticity theories explain how EF and motor skills develop together through environmental interactions, and a relative strength in one may compensate for a weakness in the other (Cameron et al., 2015). Moreover, the association between the two skills is stronger among younger children (Becker et al., 2014).

Relationships between motor skills and language development

Research indicates that Broca's area (Brodmann Area 44) is significantly activated during manual actions and plays a crucial role in understanding and mimicking actions, as well as organizing sequential tasks (Binkofski et al., 1999; Corballis, 2003; Gerardin et al., 2000). This area is essential for both speech and gesture production, highlighting the overlap between motor and perceptual mechanisms in communication (Brown & Yuan, 2018; Nishitani et al., 2005).

Motor and language development is facilitated through social interactions, such as play, where children's engagement in physical activities enhances their language skills; the ability to regulate behavior is linked to EF, which further supports the development of language competencies (Leonard & Hill ,2015); Reikerås et al., 2020).

The relationship between EF and motor skills in children with DLD has received limited attention in research so far; further exploration is needed, as this neurodevelopmental disorder may disrupt these connections.

Research goals and hypotheses

Our study's primary objective was to deepen the relationship between EF and DLD, investigating which core EF components—specifically inhibition, working memory, and cognitive flexibility (set-shifting)—contribute the most to the discrimination between preschool children with and without DLD and using age-appropriate tests. Moreover, it aims to assess whether EF is independent of non-verbal intelligence in the DLD population and explore the connections between EF, cognitive flexibility, motor skills, and planning abilities in children with DLD. To our knowledge, prior research has not consistently addressed all these relationships simultaneously in a group of preschool children with DLD; thus, our study can provide novel insights into the nature of DLD problems.

The study hypothesizes that children with DLD will show significant deficits in EF, particularly in cognitive flexibility and inhibition, in line with most of the results on preschoolers (Bishop et al., 2014; Roello et al., 2015), and that these deficits will correlate with challenges in fine motor skills and planning, in agreement with the literature on the relationship between EF and motor skills examined in the introduction (e.g., McClelland & Cameron, 2019).

Before conducting hypothesis testing, we compared the Performance IQ (PIQ) and Verbal IQ (VIQ) of the DLD group using the Wechsler Preschool and Primary Scale of Intelligence (WPPSI-III) (Sannio Fancello et al., 2008). This comparison aimed to assess whether the PIQ was significantly higher than the VIQ, as documented in the literature (e.g., Saar et al., 2023), thereby supporting the diagnostic criteria used to select DLD children for our study.

Method

Participants

The study included 22 preschool children diagnosed with Developmental Language Disorder (DLD), aged between 3:10 (years and months) to 5:6, consisting of 15 males and seven females. Participants with a Performance IQ (PIQ) of 85 or higher were recruited from an Italian Child Neuropsychiatry Unit. A thorough screening was conducted to exclude children who could not comprehend test instructions, ensuring meaningful engagement with assessment tasks. The DLD group was matched with a control group of typically developing children, also comprising 15 males and seven females, aged between 4:0 and 5:6, selected from a larger pool of 346 typically developing preschoolers who had been previously screened at school for EF and cognitive abilities. None of the children in the control group had been diagnosed with neuropsychological, sensory-motor, or language deficits, nor with learning difficulties.

By focusing on children aged 3:10 to 5:6, we aimed to capture a critical developmental window during which EF begins to show substantial growth while remaining highly malleable. Children's language skills develop rapidly, enabling the detection of subtler differences between those with and without DLD. Preschoolers in this age range also possess sufficient cognitive and attentional capacity to complete standardized tasks, such as the BAFE battery, which is normed for ages 3–6, while still being young enough that their EF skills are not influenced by formal schooling.

Material

Cognitive level assessment:
The control group's Performance IQ (PIQ) was assessed using the non-verbal Leiter-R test (Roid et al., 2013) based on school

screening. The Leiter-R was not administered to the DLD group to prevent test overload, as the PIQ was only needed for inclusion criteria.

The WPPSI-III is an intelligence test aimed at assessing the cognitive abilities of children aged 2:6 to 7:7. For children aged 4:0 to 7:3, the test includes indices for Verbal IQ (VIQ), Performance IQ (PIQ), Full-Scale IQ (FSIQ), General Language Composite (GLC), and Processing Speed Quotient (PSQ). For the younger age range of 2:6 to 3:11, the test includes indices for Verbal IQ (VIQ), Performance IQ (PIQ), Full-Scale IQ (FSIQ), and Language Composite (GLC).

The reliability indices for Performance IQ (PIQ) and Verbal IQ (VIQ) in children aged 3 to 6 years range from .88 to .94 (Sannio Fancello et al., 2008). The WPPSI-III manual reports construct and convergent validity data, indicating that the test measures a single factor related to general cognitive intelligence with strongly related subtests.

The Leiter-R (Roid et al., 2013) is a non-verbal test designed to measure IQ and cognitive ability, particularly for children and adolescents aged 2 to 20 years with cognitive delays and verbal disorders. It focuses on fluid intelligence, reducing susceptibility to linguistic, cultural, social, and educational influences. The manual reports internal consistency reliability ranging from 0.88 to 0.93, along with extensive evidence of the test's validity since its initial version (Leiter, 1979).

Executive functioning assessment

The BAFE Test, developed by Valeri et al. (2015) and Stievano et al. (2017), is an Italian neuropsychological battery designed to assess executive functioning in preschoolers aged 3 to 6 years, with tasks specifically tailored to their age and comprehension level. Each subtest targets a specific subdomain of executive function. The standardized sample for the test included 210 children, evenly distributed by gender, and represented various socioeconomic backgrounds from different regions in Italy.

The *Day and Night* task is a Stroop-like assessment that evaluates inhibition. The examiner engages the children in conversation about when the sun rises (during the day) and when the moon and stars appear (at night). He then presents a white card with a drawing of a yellow sun and a black card with a drawing of a white moon and stars. Children are told that this game requires them to say "night" for the sun card and "day" for the moon/stars card. There are 16 items, and the score range is 0-16.

Card sorting assesses set-shifting (cognitive flexibility) and is related to a Shift type in which conflict occurs at the response stage. Children sort cards into two boxes based on shape and, after five correct trials, on color. Set-shifting is examined through the children's ability to switch from one categorization criterion to another during the test. Scores range from 0 to 5.

The Pattern Making Test assesses attentional flexibility related to a Set-shifting type in which conflict occurs at the perceptual stage rather than the response stage. The child is first shown a long strip of 18 cards formed by six triplets of colored circles that repeat in the same sequence (blue, blue, red). The examiner asks the child to name each color in turn and, after, says, "Yes, you see, it makes a pattern: blue-blue-red, blue-blue-red," emphasizing the words rhythmically. The examiner then instructs the child to try and make exactly the same pattern on a steel rule using a set of red and blue magnets. Scoring is based on the number of correct triplets (0-6).

Spin the Pots evaluates visuospatial working memory. The test is administered using a rotating tray with eight different colored cups. A red ring is placed under each cup, and a cloth covers the game. After the tray is rotated, the child is asked to lift the cloth and choose a cup to find a red ring. The child must recover all the rings, and the position of the cups changes each time. This procedure is repeated until eight rings have been found or after 15 trials have been conducted (according to which was completed sooner). An error score is calculated by subtracting the maximum correct score (8) from the number of attempts the child makes to find the objects (max 15). The error score ranges between 0 and 7.

As reported in the battery manual (Valeri et al., 2015), the Kuder-Richardson 20 (KR-20) reliability indices are 0.77 for the Card Sort, 0.92 for Night & Day, and 0.92 for the Pattern Making test. The K-R20 index is not applicable to the Spin the Pots test, as it yields a single score; however, this test has been shown to correlate with the TOL test significantly and to be independent of the other EF tests included in the BAFE battery (Stievano et al., 2017). A Confirmatory Factor Analysis revealed significant factorial loading, confirming the battery's construct validity (Valeri et al., 2015).

Motor skills assessment

The Movement Assessment Battery for Children's Second Edition (MABC-2; Henderson et al., 2007) is a standardized test that can be administered to children aged 3:0 to 16:11. The test accommodates four age bands, with items differing for each age band that cover the same types of skills. The MABC-2 also includes an observational checklist. The test consists of eight items that evaluate fundamental movement skills grouped under the headings of manual dexterity (posting coins in a bank box, threading beads, drawing a line into a trail), ball skills (catching a bean bag, rolling a ball into a goal), and balance (standing on one leg, jumping over a cord, walking heels raised on a line). Test administration can take 20-30 minutes. Each item score was converted to a scaled score (0–5). The total impairment score is the sum of eight individual scores, resulting in a score between 0 and 40. Subscores were calculated by adding the three scores for manual dexterity (range: 0-15), two ball skill scores (range: 0-10), and three balance items (range: 0-15). Lower scores indicated better performance. The total motor impairment score was converted to a percentile score.

The reliability indices for age groups 2:6-2:11, 3:0-3:5, 3:6-3:11, 4:0-4:5, 4:6-4:11, 5:0-5:5, 5:6-5:11, 6:0-6:7, and 6:8-7:3 are .89, .90, .88, .94, .92, .92, .89, .90, and .89, respectively (Brown & Lalor, 2009). MABC-2 provides evidence of the ability to discriminate between particular ages or diagnosis groups, which can be considered to support its content validity (Griffiths et al., 2018).

Planning and problem-solving assessment

The Tower of London Test (ToL Test; Sannio Fancello et. al. 2006) is a neuropsychological assessment tool used to measure executive planning and problem-solving abilities. The ToL Test can be administered to subjects aged 4 to 13 years. In this test, participants were presented with a set of three distinct pegs of varying heights and a series of colored beads placed on these pegs. The objective was to rearrange the beads to match the target configuration while adhering to specific rules. Participants must plan and execute a series of moves to reach the target configuration in as few steps as possible, which requires higher-order cognitive processes such as WM, cognitive flexibility, and strategic planning. The test outcome provides valuable insights into an individual's executive and frontal lobe function.

This task is a simplified adaptation of Shallice's (1982) disk-transfer task, originally designed to assess planning abilities in individuals with brain damage. It involves higher-order cognitive skills, such as goal recognition and plan generation (Shallice, 1982). Hughes et al., (1998) modified this task to make it suitable for children by using the same-sized colored sponge balls instead of differently-sized disks and reducing the number of possible moves. Performance was coded based on the number of problems solved at each level, which ranged from zero to three.

The TOL test-retest reliability coefficient reported in the NEPSY manual for children aged 3-6 years is approximately .89 (Korkman et al., 1998). Moreover, Unterrainer et al. (2020) administered different versions of the TOL to 178 TD children aged 6 to 13 years, finding that the reliability indexes "greatest lower bound estimates of reliability" ranged from .76 and .80. Employing the framework of factor analysis and item response theory Debelak et al. (2016) evidenced the TOL's construct validity as measuring planning ability in terms of an unidimensional cognitive function.

Language comprehension assessment

The Assessment of Language Comprehension Test (Prove di valutazione della comprensione linguistica - PVCL; Rustioni, 1994) is a widely used test to assess language comprehension in Italian children aged 3 to 8 years. It evaluates an individual's ability to understand spoken language. The test involved presenting the subjects with 78 pictorial boards, each composed of four options, and asking them to select the target image based on the sentence they had heard. Sentences contain salient morphosyntactic cues, such as gender and number agreement, conjunction, negation, and different types of phrasal structures (i.e., relative, passive, temporal). One point was credited for each correct answer. Raw scores can be converted into weighted scores ranging from 0 to 100.

The test-retest reliability was .93 (Nicastri et al., 2021). The test validity is demonstrated by the significant correlations with other linguistic measures found in different studies (e.g., Florit et al., 2011).

Procedure

Both groups were evaluated on EF using the BAFE battery, with cognitive levels measured using the WPPSI-III for the DLD group and the Leiter-R for the control group. The DLD group also completed additional assessments, including the MABC-2, PVCL, and Tower of London tests. Data collection took place in a single session lasting 30-60 minutes for the control group and 60-90 minutes for the DLD group, with breaks as needed. Trained psychologists tested children in the DLD group at a national health system outpatient facility, while the control group was assessed in a quiet school area. The scoring was verified for accuracy by the administering psychologist, two trained psychology students, and a research team leader.

Ethical statement. Parental consent was requested for the children's participation in the research, and ethical approval was obtained from the health service to which the first author belongs (ASL Roma 2). According to this institutional procedure, a formal review with a registered protocol number is mandatory only for clinical trials or other interventional studies. As the present investigation did not constitute a clinical trial and relied exclusively on retrospective data from existing medical records and routine school screening, no official protocol registration was required. Nevertheless, this study complied fully with all relevant legislation, data protection regulations, and ethical standards, including the principles outlined in the Declaration of Helsinki. All patient data and school-screening data were anonymized and handled in accordance with national privacy laws.

Statistical analyses

We did not conduct a priori power analysis to determine the sample size, as the selection was motivated by practical considerations rather than statistical methods. Specifically, recruiting children with Developmental Language Disorder (DLD) who share similar characteristics, such as age, Performance IQ (PIQ), and other relevant criteria, poses significant challenges in a public clinical setting. Some authors (e.g., Bacchetti et al., 2011) argue that the need for large sample size to achieve high statistical power can dampen innovation, as studies exploring new concepts often start with a small number of cases (sometimes just one), and the effort to obtain large samples entails costs that many clinical services cannot afford. Given these concerns, we chose not to implement stringent corrections, like the Bonferroni method, to the p-value in the correlational analysis to prevent further reducing statistical power. Instead of relying only on p-values, we also considered effect sizes, as they offer a better indication of the strength of associations, especially in small samples, and are less influenced by sample size fluctuations (Bakker et al., 2019). Cohen (1988) proposed $r = .10$, $r = .30$, and $r = .50$ as benchmarks for small, medium, and large effect sizes, respectively, to interpret the strength of a correlation and estimate its power; however, these benchmarks were not derived from a systematic, quantitative analysis of data. More recently, Gignac and Szodorai (2016) analyzed 708 meta-analytically derived correlations from individual differences research and found that the normative guidelines for small, medium, and large effect sizes should be $r = .15$, $r = .25$, and $r = .35$, respectively.

A repeated-measure one-way ANOVA assessed the difference between PIQ and VIQ in the DLD group.

The EF performance of the DLD and Control groups was compared using Discriminant Analysis, which verifies whether some predictor variables, considered simultaneously, significantly discriminate between groups (by a significant Wilks' Lambda value) and determines which predictor variables uniquely contribute to group differences (by significant Partial Lambda coefficients). All the BAFE battery (EF) test scores were transformed into error scores to ensure consistency, as one of the tests (Spin the Pots) only considers the error score. A low range of errors (from 0 to 3) was observed for both set-shifting tests, namely the Card Sort and the Pattern Making Task. Consequently, we decided to calculate a single set-shifting score by summing the errors made by each child in these two tasks, which results in an error score ranging from 0 to 6. Thus, the EF predictors in the Discriminant Analysis were as follows: Inhibition (Night & Day errors), Set Shifting (summed errors from the Card Sort and Pattern Making Task), and Visuospatial WM (Spin the Pots errors).

Given the limited sample size of the DLD group, the correlations between EF (BAFE), PIQ, motor coordination (MABC-2), and planning (Tower of London) were calculated using the non-parametric Spearman's rank test.

Results

Comparison of PIQ and VIQ in DLD Children

The skewness values for PIQ and VIQ in DLD children were -0.32 and 0.23, respectively, while the kurtosis values were -0.75 and -1.09. The repeated measures ANOVA conducted on the two scores revealed a significant difference, $F(1, 21) = 9.59$, $p < .01$ (*partial* $\eta 2 = 0.31$), with PIQ being greater than VIQ ($M = 109.7$ and 101.4; $SD = 11.8$ and 13.2, respectively). This finding supports existing literature regarding the discrepancy between PIQ and VIQ in DLD children (e.g., Saar et al., 2023) and aligns with the diagnostic criteria used in this study to select the DLD group.

Age and cognitive level of the DLD and Control groups

Table 1 shows descriptive data on the age and Performance IQ of the DLD and Control groups, whose mean ages were about equal (59.18 and 59.13 months). The cognitive tests (WPPSI-III or Leiter-R) revealed that the cognitive levels of the two groups (DLD and Control) were very similar, with $M = 109.72$ and 109.50, respectively, and $SD = 11.78$ and 9.66, respectively.

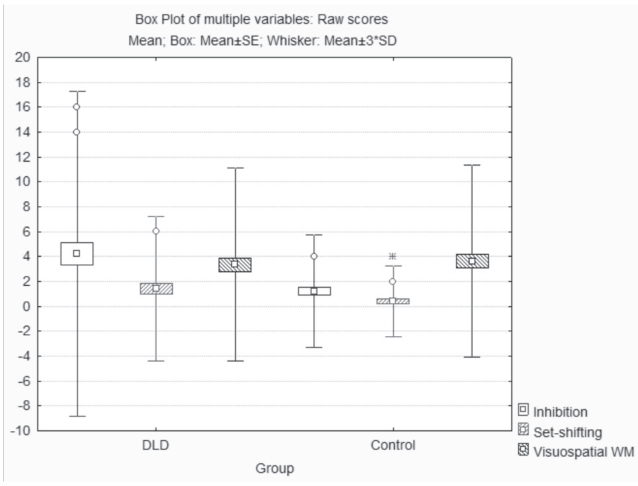
Tab. 1. Age and Performance IQ (PIQ) of DLD and Control groups.

	Age (months)		PIQ	
Sample	**M**	**SD**	**M**	**SD**
DLD group	59.18	5.14	109.72	11.78
Control group	59.13	4.96	109.50	9.66
All groups	59.15	4.99	109.61	10.64

Verifying the assumptions of Discriminant Analysis

Descriptive statistics for EF variables indicated that Inhibition (Night & Day errors) and Set-shifting (Card Sort and Pattern Making Task summed errors) exhibited relatively high kurtosis values (5.07 and 3.38, respectively), suggesting departure from normality. Tabachnick & Fidell (2013) state that Discriminant Analysis is robust against violations of normality and homoscedasticity, provided there are equal sample sizes with at least 20 cases per group and no more than five predictors. However, they warn that this analysis is sensitive to outliers. As the authors suggest checking for outliers with z scores greater than |3|, we created a Box Plot for the raw EF scores, setting the Box at Means ± SE and the Whisker at Means ± 3SD. The Box Plot is shown in Figure 1, which denotes the presence of outliers in the Control group for Set-shifting.

Fig. 1. Box Plot of EF raw scores by Groups. The asterisk denotes the presence of one or more outliers (z > 3) among the Set-shifting scores of the Control group.



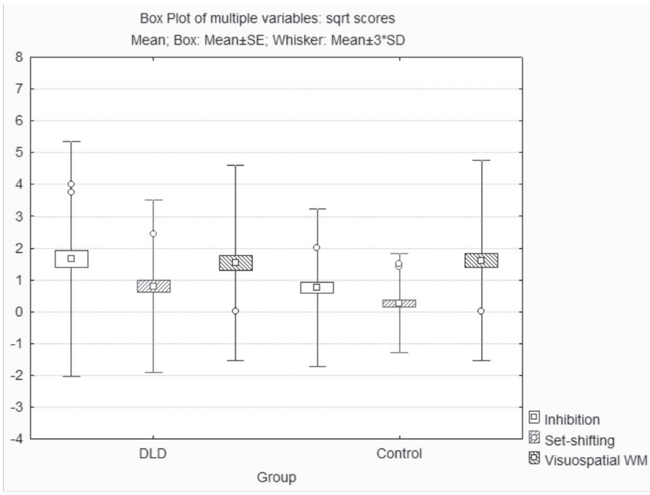
An inspection of Set-shifting z-scores revealed only one outlier with z = 3.7. Given the relatively high kurtosis values and the presence of this outlier, we decided to transform the EF raw scores into square root (sqrt) scores, which is a common method for normalizing data (Tabachnick & Fidell, 2013). After the transformation, the three kurtosis values ranged from -1.12 to -0.15, while the skewness values ranged from -0.74 to 1.10. An inspection of sqrt scores identified an outlier in the Control group for Set-shifting, with a sqrt z score of 3.1, corresponding to a sqrt score of 1.9. Following the suggestions of Tabachnick & Fidell (2013) to mitigate the impact of outliers, we assigned the outlying case a sqrt score that was one unit higher than the next smallest sqrt score that was not an outlier (1.4), thus reducing the outlier's score from 1.9 to 1.5. Figure 2 shows the Box Plot of the sqrt EF measures, demonstrating that no outliers were present after the transformations applied to the EF scores.

Table 2 presents the means and standard deviations of both the raw and square root transformed EF error scores for the DLD and Control groups, indicating that the EF error scores were higher in the DLD group, except for the Visuospatial WM task.

Tab. 2. Group means and standard deviations of EF raw and squared root (sqrt) error scores

Groups	Raw error scores						Sqrt error scores					
	Inhibition		Set-shifting		Visuospatial WM		Inhibition		Set-shifting		Visuospatial WM	
	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD
DLD group	4.23	4.36	1.41	1.94	3.36	2.57	1.67	1.23	.80	.90	1.54	1.03
Control group	1.23	1.51	.41	.96	3.64	2.57	.76	.82	.27	.52	1.61	1.04
All groups	2.73	3.57	.91	1.60	3.50	2.55	1.22	1.13	.53	.77	1.57	1.02

Fig. 2. Box Plot of EF sqrt scores by Groups. The absence of asterisks denotes the lack of outliers.



Results of the Discriminant Analysis on EF sqrt error scores

The set of EF variables (Inhibition, Set-shifting, and Visuospatial WM) significantly discriminated between DLD and Control groups (*Wilks' Lambda* = .75; approximated $F(3, 40) = 4.47$; $p < .01$), accounting for 25% of the total variance. The tolerance values ranged from .90 to .99, thus excluding multicollinearity problems (Tabachnick & Fidell, 2013). The classification matrix revealed that 70.5% of the cases were correctly classified based on the three EF scores (64% of the DLD group and 77% of the control group). The unique contributions of the three EF scores are presented in Table 3.

Tab. 3. Contributions of the EF sqrt error scores to the discrimination between DLD and Control groups

	Wilks' Lambda	Partial Lambda	F-remove (1, 40)	p-value	Stand. Coeff. for canonical variable
Inhibition	.88	.85	7.06	.01	.81
Set-shifting	.83	.90	4.27	< .05	.62
Visuospatial WM	.76	.99	.43	.52	.22

The variable that contributed most to group discrimination was Inhibition, which had the highest standardized coefficient for the canonical variable (.81). The Inhibition error scores significantly differentiated the two groups independently of the other variables, as evidenced by the lowest Partial Lambda (.85) and the significant F value ($F(1, 40) = 7.06$; $p = .01$). The second variable that contributed significant variance was Set-shifting, which had a standardized coefficient of .62 and a unique contribution (Partial Lambda) of .90, with $F(1, 40) = 4.27$ and $p < .05$.

Correlations between measures in the DLD group

Table 4 shows Spearman's rank correlations in the DLD group of the three EF variables with Performance IQ, motor coordination, verbal comprehension, and planning scores. According to Gignac and Szodorai's (2016) guidelines, some "large" effects ($r > .35$) are present in Table 4. Specifically, these effects pertain to the correlation between Inhibition and PVCL ($r = -.45$), as well as the correlations of Set-shifting with PVCL, MABC-2, and the Tower of London ($r = -.44$, $r = -.39$, and $r = -.44$, respectively). All of these correlations were significant at $p < .05$, except for the one between Set-shifting and MABC-2, which only approached significance ($p < .08$). The correlations between the EF error scores and the Performance subtest of the WPPSI-III (PIQ) were low or medium and statistically non-significant, showing that the EF variables considered in the present work are independent of the non-verbal intelligence level of DLD children.

Since EF scores reflect the errors made by children in these tasks, the results in Table 4 suggest that children in the DLD group with lower levels of verbal comprehension face the greatest challenges with inhibition and cognitive flexibility. This effect is evident in increasing errors in Inhibition (Night & Day task) and Set-shifting (Card Sort and Pattern Making Task combined score) in children with lower performance in the PVCL test. Moreover, weak set-shifting was linked to inadequate planning abilities (Tower of London) and poor motor coordination (MABC-2).

Tab. 4. Spearman correlations of EF sqrt error scores with Performance IQ (PIQ), verbal comprehension (PVCL), motor coordination (MABC-2), and planning scores (Tower of London) in the DLD group

Variables	Inhibition	Set-shifting	Visuospatial WM
PIQ	-.29	-.26	.10
PVCL	-.45*	-.44*	.32
MABC-2	-.19	-.39	-.18
Tower of London	-.05	-.44*	.26

*$p < .05$

Discussion

The present study examined core executive functions (EFs)—specifically inhibition, working memory, and cognitive flexibility—and their relationship with planning and motor skills in preschool children with Developmental Language Disorder (DLD). Unlike previous studies mainly focusing on isolated domains, our work uniquely integrates executive, motor, and planning dimensions in preschoolers with DLD, providing a multidimensional developmental profile.

Our main finding indicates that the full set of EF scores accounted for significant variance in the discrimination between children with DLD and their typically developing peers. Among the individual EF measures, inhibition was the strongest contributor to group differentiation, consistent with previous research on preschool populations (Bishop et al., 2005; Marini et al., 2020; Roello et al., 2015). This finding is particularly relevant, as inhibitory control plays a crucial role in early verbal development, by regulating conversational turn-taking, suppressing irrelevant linguistic responses, and supporting syntactic processing (Marini et al., 2020). Regarding Set-shifting, we found that this measure explained significant variance in group discrimination and was lower in DLD children with poorer language comprehension (PVCL). Interestingly, Oshchepkova et al. (2021) found that a set-shifting measure based on a card sorting task was significantly correlated with language production ability in typically developing children aged 5 to 6 years. This pattern of results emphasizes the importance of cognitive flexibility in the development of various language domains.

In contrast, visuospatial working memory (WM), assessed through the "Spin the Pots" task, showed comparable performance across groups. This result diverges from the findings by Niu et al. (2024), who reported impairments in both verbal and visuospatial WM in preschoolers with DLD. However, their study also emphasized that verbal WM deficits are more consistent and age-independent, while visuospatial WM may be more sensitive to task demands and developmental stage. Future studies should include a broader range of visuospatial WM tasks to better characterize potential domain-specific deficits in DLD.

Importantly, no significant correlations were found between EF scores and nonverbal intelligence (Performance IQ, PIQ) in the DLD group. In contrast, a lower Verbal IQ, consistent with previous findings (Saar et al., 2023), was confirmed. This supports the hypothesis that EF difficulties in DLD are not simply attributable to general cognitive delay and underscores the value of independently assessing EF, even in children with average PIQ scores.

A particularly novel contribution of this study is the positive associations observed in children with DLD between cognitive flexibility, motor abilities, and planning. These results align with the findings of Becker et al. (2014) and Cameron et al. (2015), who observed strong relationships between EF measures and visuomotor skills in typically developing children. Specifically, visuomotor skills and inhibitory control were found to interact, proposing a reciprocal developmental relationship between motor and executive systems, and suggesting that early motor experiences may contribute to the maturation of cognitive control networks. This opens promising directions for intervention programs that integrate motor and cognitive training in early childhood settings. Our findings also point to a potential overlap in neural networks supporting language, fine motor coordination, and balance, highlighting the importance of assessing EF in early childhood.

Limitations

The primary limitation of our study was the small size of the DLD group, which resulted from practical constraints. In our service, families voluntarily bring their children for assessment, and the availability of cases that meet strict inclusion criteria is inherently limited, as research must rely on naturally occurring patient flows. Consequently, gathering a large, homogeneous sample requires significant time. Among the study's limitations, we also highlight the cross-sectional design, which prevents causal inferences, and the use of two different tests for PIQ assessment.

Despite these limitations, the large screening sample used to select the TD group allowed for effective matching in terms of PIQ, age, and gender, which supports the validity of our group comparisons. Additionally, our results align with previous findings in the literature, further supporting their validity.

It is essential to emphasize that the correlational analysis conducted in this study is exploratory and preliminary. Therefore, we recommend interpreting significant correlations with caution, pending replication in larger samples. Since this is the first study to examine these relationships within this specific age range and population, our objective was not to draw definitive conclusions but to provide a foundational basis for future longitudinal research aimed at clarifying the directionality of the observed associations and assessing their changes with development.

Conclusion and clinical implications

The results of this study extend the existing literature by employing multiple EF measures instead of isolated tasks, offering a more comprehensive view of executive dysfunction in children with DLD and reinforcing the need for a deeper understanding of the role of EF in early language development, consistent with the perspectives proposed by Shokrkon and Nicoladis (2022). The weaknesses in inhibition and cognitive flexibility observed in children with DLD suggest a broader profile of executive vulnerability that may amplify existing linguistic challenges. This makes these functions a crucial target for early intervention.

Our findings highlight the importance of considering executive functioning, particularly inhibition and cognitive flexibility, as central components in the developmental profile of preschool children with DLD. These functions should not be addressed in isolation but rather embedded within a comprehensive educational and rehabilitative framework that integrates language support with neuropsychological intervention.

From an educational perspective, fostering EF can enhance children's ability to manage classroom tasks, follow instructions, and regulate behaviour, ultimately improving learning outcomes. Interventions should include structured routines, visual supports, and metacognitive strategies to strengthen self-regulation and planning.

On the rehabilitation side, combining language therapy with activities that promote motor coordination and executive planning—such as play-based tasks, problem-solving games, and sequential motor routines—may amplify therapeutic effects. An integrated model that links linguistic stimulation with executive and motor training leverages shared neural pathways and developmental synergies, promoting more robust and generalized improvements.

This integrative approach underscores the need for interdisciplinary collaboration among educators, speech-language pathologists, neuropsychologists, and occupational therapists, with individualized programs grounded in a dynamic understanding of each child's cognitive-linguistic profile.

Ethical Approval

Parental consent was requested for the children's participation in the research, and ethical approval was obtained from the health service to which the first author belongs (ASL Roma 2). According to this institutional procedure, a formal review with a registered protocol number is mandatory only for clinical trials or other interventional studies. As the present investigation did not constitute a clinical trial and relied exclusively on retrospective data from existing medical records and routine school screening, no official protocol registration was required. Nevertheless, this study complied fully with all relevant legislation, data protection regulations, and ethical standards, including the principles outlined in the Declaration of Helsinki. All patient data and school-screening data were anonymized and handled in accordance with national privacy laws.

Data Availability Statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Conflict of Interests

The authors declare that they have no conflict of interests.

Author Contributions

PS and DA designed the study and wrote the main draft; DA and BT collected and analyzed the data; SM and GV contributed to the interpretation of the results; TGS contributed to the statistical analyses and supervised the manuscript.. All authors approved the final version of the manuscript.

No supplementary materials are associated with this article.

References

American Psychiatric Association. (2013). American Psychiatric Association. *Diagnostic and statistical manual of mental disorders: DSM-5*, Washington D.C., American Psychiatric Association; trad. it. DSM-5. *Manuale diagnostico e statistico dei disturbi mentali*, Milano, Cortina, 2014.

Archibald, L. M. D. (2024). On the many terms for developmental language and learning impairments. In L. M. D. Archibald, *Discover Education* (Vol. 3, Issue 1). Springer Science+Business Media.

Ardila, A. (2012). Interaction between lexical and grammatical language systems in the brain. *Physics of life reviews*, 9(2), 198-214. https://doi.org/10.1016/j.plrev.2012.05.001

Bacchetti, P., Deeks, S. G., & McCune, J. M. (2011). Breaking free of sample size dogma to perform innovative translational research. *Sci. Transl. Med*. 3, 1–4. doi: 10.1126/scitranslmed.3001628

Bakker, A., Cai, J., English, L., Kaiser, G., Mesa, V., & van Dooren, W. (2019). Beyond small, medium, or large: Points of consideration when interpreting effect sizes. *Educational Studies in Mathematics*, 102(1), 1–8. https://doi.org/10.1007/s10649-019-09908-4

Becker, D. R., Miao, A., Duncan, R., & McClelland, M. M. (2014). Behavioral self-regulation and executive function both predict visuomotor skills and early academic achievement. *Early Childhood Research Quarterly*, 29(4), 411-424. https://doi.org/10.1016/j.ecresq.2014.04.014

Berthelsen, D., Hayes, N., White, S. L., & Williams, K. E. (2017). Executive function in adolescence: Associations with child and family risk factors and self-regulation in early childhood. *Frontiers in Psychology*, 8, 903. https://doi.org/10.3389/fpsyg.2017.00903

Binkofski, F., Buccino, G., Posse, S., Seitz, R. J., Rizzolatti, G., & Freund, H. J. (1999). A fronto-parietal circuit for object manipulation in man: evidence from an fMRI-study. *European Journal of Neuroscience*, *11*(9), 3276-3286. DOI: 10.1046/j.1460-9568.1999.00753.x

Bishop, D. V. M. (2002). The role of genes in the etiology of specific language impairment. *Journal of Communication Disorders*, *35*(4), 311-328. DOI: 10.1016/s0021-9924(02)00087-4

Bishop, D. V., Nation, K., & Patterson, K. (2014). When words fail us: insights into language processing from developmental and acquired disorders. *Philosophical Transactions of the Royal Society B: Biological Sciences, 369* (1634), 20120403. doi: 10.1098/rstb.2012.0403

Bishop, D. V., & Norbury, C. F. (2005). Executive functions in children with communication impairments, in relation to autistic symptomatology. 2: *Response inhibition. Autism, 9*(1), 29-43. https://doi.org/10.1177/1362361305049028

Bolam, J. P., Brown, M. T., Moss, J., & Magill, P. J. (2009). *Basal Ganglia: Internal Organization*. In J. P. Bolam, M. T. Brown, J. Moss, & P. J. Magill, Elsevier eBooks (p. 97). Elsevier BV. https://doi.org/10.1016/b978-008045046-9.01294-8

Brown, S., & Yuan, Y. (2018). Broca's area is jointly activated during speech and gesture production. *Neuroreport, 29*(14), 1214-1216. DOI: 10.1097/WNR.0000000000001099

Brown, T., & Lalor, A. (2009). The Movement Assessment Battery for Children—Second Edition (MABC-2): A Review and Critique. *Physical & Occupational Therapy in Pediatrics*, *29*(1), 86–103. https://doi.org/10.1080/01942630802574908

Cameron, C. E., Brock, L. L., Hatfield, B. H., Cottone, E. A., Rubinstein, E., LoCasale-Crouch, J., et al. (2015). Visuomotor integration and inhibitory control compensate for each other in school readiness. *Developmental Psychology,* 51(11), 1529–1543. http://dx.doi.org/10.1037/a0039740

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences (2nd ed.)*. Hillsdale, NJ: Erlbaum.

Corballis, M. C. (2003). From mouth to hand: gesture, speech, and the evolution of right-handedness. *Behavioral And Brain Sciences, 26*(2), 199-208. doi: 10.1017/s0140525x03000062.

Debelak, R., Egle, J., Köstering, L., & Kaller, C. P. (2016). Assessment of planning ability: Psychometric analyses on the unidimensionality and construct validity of the Tower of London Task (TOL-F). *Neuropsychology*, 30(3), 346–360. https://doi.org/10.1037/neu0000238

Diamond, A. (1995). Evidence of robust recognition memory early in life even when assessed by reaching behavior. *Journal of Experimental Child Psychology, 59*, 419–456. https://doi.org/10.1006/jecp.1995.1020

Diamond, A. (2013). Executive functions. *Annual Review of Psychology*, 64, 135-168. https://doi.org/10.1146/annurev-psych-113011-143750

Diamond, A. (2000). Close interrelation of motor development and cognitive development and of the cerebellum and prefrontal cortex. *Child Development, 71*(1), 44-56. doi: 10.1111/1467-8624.00117

Florit, E., Roch, M., & Levorato, M. C. (2011). The relationship between listening comprehension of text and sentences in preschoolers: Specific or mediated by lower and higher-level components? *Applied Psycholinguistics*, 34(2), 395–415. doi:10.1017/S0142716411000749

Foglia L, Wilson RA. (2013). Embodied cognition. *WIREs Cogn Sci,* 4:319–325. doi: 10.1002/wcs.1226

Garon, N., Bryson, S. E., & Smith, I. M. (2008). Executive function in preschoolers: a review using an integrative framework. *Psychological Bulletin, 134*(1), 31–60. https://doi.org/10.1037/0033-2909.134.1.31

Gerardin, E., Sirigu, A., Lehéricy, S., Poline, J. B., Gaymard, B., Marsault, C., Agid, Y., & Le Bihan, D. (2000). Partially overlapping neural networks for real and imagined hand movements. *Cerebral Cortex (New York, N.Y. : 1991), 10*(11), 1093–1104. https://doi.org/10.1093/cercor/10.11.1093

Gignac, G. E., & Szodorai, E. T. (2016). Effect size guidelines for individual differences researchers. *Personality and Individual Differences*, 102, 74–78. https://doi.org/10.1016/j.paid.2016.06.069

Griffiths, A., Toovey, R., Morgan, P. E., & Spittle, A. J. (2018). Psychometric properties of gross motor assessment tools for children: a systematic review. *BMJ open*, *8*(10), e021734. doi: 10.1136/bmjopen-2018-021734

Henderson, S. E., Sugden, D. A., & Barnett, A. L. (2007). *Movement Assessment Battery for Children-2 second edition (Movement ABC-2).* London, UK: The Psychological Corporation.

Henry, L. A., Messer, D. J., & Nash, G. (2012). Executive functioning in children with specific language impairment. *Journal of Child Psychology and Psychiatry, 53*(1), 37-45. DOI: 10.1111/j.1469-7610.2011.02430.x

Hill, E. L. (1998). A dyspraxic deficit in specific language impairment and developmental coordination disorder? Evidence from hand and arm movements. *Developmental Medicine & Child Neurology, 40*(6), 388-395. DOI: 10.1111/j.1469-8749.1998.tb08214.x

Hill, E. L. (2001). Non-specific nature of specific language impairment: a review of the literature with regard to concomitant motor impairments. *International Journal of Language & Communication Disorders, 36*(2), 149-171. doi: 10.1080/13682820010019874

Hughes, C., Dunn, J., & White, A. (1998). Trick or treat?: Uneven understanding of mind and emotion and executive dysfunction in "hard-to-manage" preschoolers. The Journal of Child Psychology and Psychiatry and Allied Disciplines, 39(7), 981-994.

Korkman, M., Kirk, U., & Kemp, S. (1998). *NEPSY. A developmental neuropsychological assessment.* Chicago: Psychological Corporation.

Kray, L. J., Galinsky, A. D., & Wong, E. M. (2006). Thinking within the box: The relational processing style elicited by counterfactual mind-sets. *Journal of Personality and Social Psychology*, 91(1), 33–48. https://doi.org/10.1037/0022-3514.91.1.33

Kumar, U., Arya, A., & Agarwal, V. (2022). Altered functional connectivity in children with ADHD while performing cognitive control task. Psychiatry Research: Neuroimaging, 326, 111531.

Lehto, J. E., Juujärvi, P., Kooistra, L., & Pulkkinen, L. (2003). Dimensions of executive functioning: Evidence from children. *British Journal of Developmental Psychology*, 21(1), 59-80. https://doi.org/10.1348/026151003321164627

Leiter, R. G. (1979). *Instruction Manual For The Leiter International Performance Scale.* Wood Dale, IL: Stoelting Co.

Leonard, L. B. (1998). *Children With Specific Language Impairment*. Cambridge, MA: MIT PRESS.

Leonard, H. C., & Hill, E. L. (2015). Executive difficulties in developmental coordination disorder: methodological issues and future directions. Current Developmental Disorders Reports, 2, 141-149.

Lukács, Á., Ladányi, E., & Kemény, F. (2016). Executive functions and the contribution of short-term memory span in children with specific language impairment. *Neuropsychology, 30*(3), 296. doi: 10.1037/neu0000232.

Marini, A., Piccolo, B., Taverna, L., Berginc, M., & Ozbič, M. (2020). The Complex Relation between Executive Functions and Language in Preschoolers with Developmental Language Disorders. *International Journal of Environmental Research and Public Health, 17*(5), 1772. doi: 10.3390/ijerph17051772

McClelland, M. M., & Cameron, C. E. (2019). Developing together: The role of executive function and motor skills in children's early academic lives. *Early Childhood Research Quarterly*, 46, 142–151. https://doi.org/10.1016/j.ecresq.2018.03.014

Miyake, A., Friedman, N. P., Emerson, M. J., Witzki, A. H., Howerter, A., & Wager, T. D. (2000). The unity and diversity of executive functions and their contributions to complex "Frontal Lobe" tasks: a latent variable analysis. *Cognitive Psychology*, 41(1), 49–100. https://doi.org/10.1006/cogp.1999.0734

Nicastri, M., Giallini, I., Amicucci, M., Mariani, L., de Vincentiis, M., Greco, A., Guerzoni, L., Cuda, D., Ruoppolo, G., & Mancini, P. (2021). Variables influencing executive functioning in preschool hearing-impaired children implanted within 24 months of age: an observational cohort study. *European archives of oto-rhino-laryngology: official journal of the European Federation of Oto-Rhino-Laryngological Societies (EUFOS): affiliated with the German Society for Oto-Rhino-Laryngology - Head and Neck Surgery*, 278(8), 2733–2743. https://doi.org/10.1007/s00405-020-06343-7.

Nishitani, N., Schurmann, M., Amunts, K., & Hari, R. (2005). Broca's region: from action to language. *Physiology*, 20(1), 60-69. doi: 10.1152/physiol.00043.2004.

Niu, T., Wang, S., Ma, J., Zeng, X., & Xue R. (2024). Executive functions in children with developmental language disorder: a systematic review and meta-analysis. *Front. Neurosci.* 18:1390987. doi: 10.3389/fnins.2024.1390987

Oshchepkova, E., Bukhalenkova, D., & Veraksa, A. (2021). The Relation Between Cognitive Flexibility and Language Production in Preschool Children. In: Velichkovsky, B.M., Balaban, P.M., Ushakov, V.L. (eds) *Advances in Cognitive Research, Artificial Intelligence and Neuroinformatics*.

Pauls, L. J., & Archibald, L. M. (2016). Executive functions in children with specific language impairment: A meta-analysis. *Journal of Speech, Language, and Hearing Research, 59*(5), 1074-1086. doi: 10.1044/2016_JSLHR-L-15-0174

Reichenbach, K., Bastian, L., Rohrbach, S., Gross, M., & Sarrar, L. (2016). Cognitive functions in preschool children with specific language impairment. *Int. J. Pediatr. Otorhinolaryngol.* 86, 22–26. doi: 10.1016/j.ijporl.2016.04.011

Reikerås, E., Moser, T., & Tønnessen, F. E. (2020). Relations between motor skills and language skills in toddlers and preschool-aged children. *Journal for Research in Arts and Sports Education*, 4(2). DOI: 10.23865/jased.v4.2417

Roello, M., Ferretti, M. L., Colonnello, V., & Levi, G. (2015). When words lead to solutions: Executive function deficits in preschool children with specific language impairment. *Research in Developmental Disabilities, 37*, 216-222. doi: 10.1016/j.ridd.2014.11.017

Roid, G. H., Miller, L. J., & Koch, C. (2013). *Leiter international performance scale.* Wood Dale, IL: Stoelting.

Rustioni, D. (1994). *Prove di valutazione della comprensione linguistica*. Firenze: Organizzazioni Speciali.

Saar, V., Komulainen E., & Levänen S. (2023) The significance of nonverbal performance in children with developmental language disorder, *Child Neuropsychology,* 29:2, 213-234, DOI: 10.1080/09297049.2022.2077324

Sannio Fancello, G., Vio, C., & Cianchetti, C. (2006). *TOL. Torre di Londra. Test di valutazione delle funzioni esecutive (pianificazione e problem solving).* Trento: Edizioni Erickson.

Sannio Fancello, G., & Cianchetti, C. (Eds.). (2008). *Wechsler Preschool and Primary Scale of Intelligence - Third Edition (WPPSI-III). Edizione italiana*. Firenze: Giunti O.S. Organizzazioni Speciali.

Shallice, I. (1982). *Tower of London test.* Tehran: Sina Research Institute of Behavioral Cognitive Science (ravantajhiz), 1387.

Shokrkon, A., & Nicoladis, E. (2022). The Directionality of the Relationship Between Executive Functions and Language Skills: A Literature Review. *Frontiers in Psychology, 13*, 848696. https://doi.org/10.3389/fpsyg.2022.848696

Spratt, E. G., Friedenberg, S. L., Swenson, C. C., Larosa, A., De Bellis, M. D., Macias, M. M., Summer, A. P., Hulsey, T. C., Runyan, D. K., & Brady, K. T. (2012). The Effects of Early Neglect on Cognitive, Language, and Behavioral Functioning in Childhood. *Psychology (Irvine, Calif.)*, *3*(2), 175–182. https://doi.org/10.4236/psych.2012.32026

Stievano, P., Michetti, S., McClintock, S. M., Levi, G., & Scalisi, T. G. (2016). Handwriting fluency and visuospatial generativity at primary school. *Reading and Writing*, *29*, 1497-1510. https://doi.org/10.1007/s11145-016-9648-6

Stievano, P., & Scalisi, T. G. (2016). Unique designs, errors and strategies in the Five-Point Test: The contribution of age, phonemic fluency and visuospatial abilities in Italian children aged 6–11 years. *Child Neuropsychology*, *22*(2), 197-219. doi: 10.1080/09297049.2014.988607

Stievano, P., Ciancaleoni, M., & Valeri, G. (2017). Italian executive functions battery for preschoolers (BAFE): working memory, inhibition, set-shifting. *Neuropsychological Trends*, *22*, 25-46. DOI:10.7358/neur-2017-022-stie

Stievano, P., Cammisuli, D. M., Michetti, S., Ceccolin, C., & Anobile, G. (2018). Cognitive processes underlying arithmetical skills in primary school: The role of fluency, handwriting, number line and number acuity. *Neuropsychological Trends*, 23, 115–138. https://doi.org/10.7358/neur-2018-023-camm

Stuss, D. T. (1992). Biological and psychological development of executive functions. *Brain and Cognition, 20*(1), 8-23. https://doi.org/10.1016/0278-2626(92)90059-U

Tabachnick, B. G., & Fidell, L. S. (2013). *Using multivariate statistics*. Pearson Education Limited: Pearson New International Edition.

Ullman, M. T., & Pierpont, E. I. (2005). Specific language impairment is not specific to language: The procedural deficit hypothesis. *Cortex, 41*(3), 399-433. https://doi.org/10.1016/S0010-9452(08)70276-4

Unterrainer, J. M., Rahm, B., Loosli, S. V., Rauh, R., Schumacher, L. V., Biscaldi, M., & Kaller, C. P. (2020). Psychometric analyses of the Tower of London planning task reveal high reliability and feasibility in typically developing children and child patients with ASD and ADHD. *Child Neuropsychology*, 26(2), 257–273. https://doi.org/10.1080/09297049.2019.1642317

Valeri, G., Stievano, P., Ferretti, M. L., Mariani, E., & Pieretti, E. (2015). *BAFE Batteria per l'Assessment delle Funzioni Esecutive*. Firenze: Hogrefe Editore.

Vygotsky, L. S., & Cole, M. (1978). *Mind in society: Development of higher psychological processes*. Harvard University Press.

Vygotsky, L. S. (1987). *Thinking and speech. The collected works of Lev Vygotsky (Vol. 1).* New York: Plenum Press, *114*, 113-114.

Zelazo, P. D., & Müller, U. (2002). Executive function in typical and atypical development. In U. Goswami (Ed.), *Blackwell handbook of childhood cognitive development* (pp. 445–469). Blackwell Publishing. https://doi.org/10.1002/9780470996652.ch20

Zelazo, P.D., Blair, C.B., & Willoughby, M.T. (2016). *Executive Function: Implications for Education* (NCER 2017-2000) Washington, DC: National Center for Education Research, Institute of Education Sciences, U.S. Department of Education. This report is available on the Institute website at http://ies.ed.gov/.

Zhang, X., Qin, F., Chen, Z., Gao, L., Qiu, G., & Lu, S. (2020). Fast screening for children's developmental language disorders via comprehensive speech ability evaluation—using a novel deep learning framework. In X. Zhang, F. Qin, Z. Chen, L. Gao, G. Qiu, & S. Lu, *Annals of Translational Medicine* (Vol. 8, Issue 11, p. 707). AME Publishing Company. https://doi.org/10.21037/atm-19-3097