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ORIGINAL ARTICLE

IQ Profiles in Bilingual Children With Developmental Language Disorder: The Role of Maternal Education

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Abstract

Purpose The intellectual profile of monolingual children with Developmental Language Disorder is typically characterized by below-average verbal IQ (VIQ) and average Performance IQ (hence, PIQ) scores. Our knowledge of IQ functioning in bilingual children with Developmental Language Disorder is still very limited. Furthermore, previous research in IQ functioning in children with Developmental Language Disorder has not addressed maternal education as a possible alternative exploratory variable affecting children's performance in IQ tests. Here, we aimed to investigate if intellectual functioning of children with Developmental Language Disorder is affected by bilingualism, and whether this relation is affected by the children's socioeconomic characteristics, including maternal and parental education, and family income.

Methods We focused on IQ profile comparisons between 125 bilingual children and 109 monolingual children with Developmental Language Disorder.

Results We found that the bilingual children exhibited 'normalized' performance in those VIQ tests that tapped into metalinguistic knowledge and social understanding. The bilingual children were also more likely to exhibit average skills across PIQ tests. Finally, we found that the positive effect of bilingualism on children's IQ was only observed for the children whose mothers had a low educational level.

Conclusion The overall findings hold implications for the broader understanding of intellectual functioning in bilingual neurodiverse populations, also highlighting the unique role of maternal education in studying children's cognitive development.

Keywords Developmental language disorder · Bilingualism · Intelligence · Verbal IQ · Performance IQ · Maternal education

Introduction

Developmental Language Disorder (DLD), formerly known as Specific Language Impairment, is a neurodevelopmental disorder primarily characterized by impairments in structural language, specifically, in morphosyntax, phonology, vocabulary, and/or discourse skills (Bishop et al., 2017; Tomblin et al., 1997). DLD has been characterized by an atypical discrepancy between children's extraordinary weakness in language and their comparatively less affected nonverbal cognitive skills, which however tend to be weaker than their peers of typical development (TD) (Liao et al., 2015; McGregor et al., 2013; Stothard et al., 1998; also see Gallinat & Spaulding, 2014 for a meta-analysis). The discrepancy between verbal and nonverbal skills in DLD has been manifested in below-average verbal IQ (henceforth, VIQ) and average nonverbal (henceforth, Performance) IQ (PIQ) scores in IQ measurement tools, though

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in the DSM-5 (American Psychiatric Association, 2013) the criterion of average PIQ is no longer relevant for DLD diagnosis due to concerns of excluding children with language and neurocognitive deficits. The current, international consensus definition of DLD (Bishop et al., 2017) underscores that VIQ-PIQ discrepancies are not relevant to DLD diagnosis, whereas low language is the defining characteristic.

Though VIQ and PIQ profiles have been investigated in monolingual children with DLD across the lifespan (Botting, 2005; Clegg et al., 2005; Conti-Ramsden et al., 2012), the potential of bilingual learning to compensate for developmental challenges in DLD is still not well-defined. Bilingualism, defined as the knowledge and active use of two or more languages, is characterized by variability conditioned by multiple factors, including the amount of input in a second language (L2), the age of first exposure to L2, the amount of code-switching between the two languages to enable production of more accessible lexical forms, and L2 proficiency, among others (Baum & Titone, 2014; Luk & Bialystok, 2013). It is assumed that the constant state of language coactivation and competition for selection, especially when co-occurring with balanced use and balanced level of proficiency in two languages (also termed *high language entropy*; Gullifer & Titone, 2018, 2019a, Gullifer and Titone 2019b), makes bilingual speakers highly skilled at managing competition and at resolving conflict in the linguistic domain (Blumenfeld & Marian, 2011), and when processing language-independent information (Bialystok et al., 2009; Green & Abutalebi, 2013; Gullifer & Titone, 2021; Yow & Li, 2015). So far, research in typically-developing (TD) children has shown bilingualism to be critical in enhancing mainly domain-general executive functioning, specifically, inhibitory control, as well as other cognitive processes, such as decision-making, attention, and memory processing (Bialystok & Craik, 2022). Together, the findings on the positive effects of bilingualism on cognition in typical development, and the lower PIQ in DLD children as compared to TD peers (Gallinat & Spaulding, 2014) infer that DLD children whose daily language exposure is divided between two languages might show higher PIQ scores than their monolingual DLD peers. A crucial hypothesis would thus be that exposure to two languages in fairly equal proportions over DLD children's lifespan would aid in maximizing cognitive outcomes, including the children's PIQ.

Besides dual language exposure, very few of the studies that have investigated nonverbal cognitive functioning in bilingual children with DLD (Ebert, 2021; Park et al., 2020) have addressed socioeconomic status (SES) as a possible alternative exploratory variable affecting DLD children's performance in nonverbal tests. Socioeconomic status is a multidimensional construct based on several parameters, such as maternal and paternal education, family income, material resources, and type of employment as well as related neighborhood and family characteristics (Bradley & Corwyn, 2002). Previous research indicates complex relations between socioeconomic position and children's cognitive abilities, also supporting differentiation of measures of socioeconomic characteristics that guide cognitive development and testing of distinct predictions regarding the mechanisms driving each cognitive process. For example, Lung et al. (2011) found that maternal education had a persisting and gradually increasing (positive) effect on different (i.e., motor, language, social) domains of development over the first three years of the child's life, while paternal education had a circumscribed, short-living effect on the child's motor development at the age of 36 months. Similarly, Jeong et al.'s (2018) large-scale study with data from 39 low-income and middle-income countries revealed that maternal and paternal education independently predicted social-emotional and learning development outcomes among preschool-aged children, however, associations were significantly stronger for maternal versus paternal education (see also Desai & Alva, 1998, Jeong et al., 2017, for similar findings). In children with DLD, Park et al.'s (2020) study found that, though the group with DLD fell behind their TD peers in processing speed, this effect disappeared when children's maternal education was considered, further suggesting that it was low maternal education level rather than DLD that had a negative relationship with processing speed measures. The overall evidence suggests that maternal and paternal education may influence the child's cognitive development through different mechanisms or pathways, and that while both measures have an independent impact on developmental outcomes, maternal education has a stronger and more enduring effect. Though the effect of maternal education on the cognitive development of children of typical development has been shown to be robust, its effect on the IQ abilities of children with DLD is largely unknown.

Assessment of intellectual functioning in monolingual children with DLD has so far focused on IQ tests, mainly due to the expectation that performance in VIQ tests would be confounded by the children's language comprehension and production difficulties. Botting (2005) has examined the developmental trajectories of PIQ in a group of 82 children with DLD who were tested on Raven's Coloured Progressive Matrices (Raven, 1986) at ages 7 and 8, the Block Design and Picture Completion subtests of WISC-III (Wechsler, 1992) at age 11, and the PIQ subscales of WISC-III at age 14. The analyses revealed a major drop in the children's PIQ scores between years 7 and 14, thus, indicating a steep deterioration in the children's PIQ functioning. In contrast to Botting (2005), Conti-Ramsden et al.'s (2012) longitudinal study of PIQ development in 242 individuals with DLD, who were followed up at age 7 up until adolescence,

found no evidence of either slowing or acceleration of PIQ for the group as a whole. However, the study has identified a subgroup showing a developmental slowdown in PIQ; the specific cluster was composed of children with lower-than-average PIQ abilities at 7 years, while groups with average or above-average PIQ at age 7 exhibited stable developmental trajectories up until adolescence. In contrast to the large individual differences in PIQ trajectories, the children with DLD exhibited stable growth in VIQ which reflected a systematic maturation of the individuals' language abilities. Saar and colleagues (2023) have recently offered a fine-grained view of the dimensions of PIQ that appear to be unaffected in pre-school aged children with DLD, such as processing speed, perceptual and abstract reasoning measured through the Matrix Reasoning and Picture Concepts PIQ subtests of the Wechsler Preschool and Primary Scale of Intelligence (Wechsler, 2009). The same study revealed that verbal reasoning and verbal short-term memory were the weakest VIQ domains in the same group. Similarly, abstract reasoning and planning ability have been shown to be of great vulnerability in school-aged Polish-speaking children with DLD (Maryniak, 2022), who were assessed on selected PIQ subtests of the ABC II Kaufman testing battery (Kaufman & Kaufman, 2004).

A common point highlighted by previous longitudinal research in intellectual functioning in DLD relates to the strong developmental dependencies between language and PIQ development at an early age. It seems that children with DLD and low language skills also show weaker PIQ performance relative to their peers with higher language abilities (Botting, 2005; Conti-Ramsden et al., 2012). While the degree to which such dependencies generalize across PIQ subtests remains unexplored, the potential impact of a PIQ advantage for DLD children with relatively mild language difficulties over their peers with severe language impairment at an early time window in the children's development can be wide ranging. Furthermore, it remains to be seen how the effects of a dependency between VIQ and PIQ skills apply to bilingual children with DLD.

To the best of our knowledge, no study has so far examined VIQ and PIQ in bilingual children with DLD. There is limited evidence from bilingual children with DLD being assessed on tasks measuring processing speed and attention. For example, Park et al.'s (2020) and Ebert 's (2021) studies with monolingual and bilingual TD children and children with DLD offer converging evidence in favor of slower processing speed for the children with DLD as compared to their TD peers independently of the children's language experience, i.e., whether they are monolinguals or bilinguals. In an earlier study, Park and colleagues (2019) found that bilingual experience had no effect on DLD and TD children's attention orienting skills, while no bilingualism effects were observed for attentional control and sustained attention skills (also see Boerma et al., 2022 for similar findings). The overall findings show null or minimal effects of bilingual experience on DLD children's processing speed and attention skills, but at the same time demonstrate that the relation between bilingualism and IQ in DLD may be modulated by child-external factors, like SES.

Due to absent comparable literature in the area of VIQ and PIQ in bilingual children with DLD, the current study aims to fill this gap by focusing on IQ profile comparisons between 125 bilingual children with DLD (hence, BI-DLD) and 109 monolingual children with DLD (hence, MO-DLD). For IQ assessment, the study has used the standardized scores of the VIQ and PIQ subscales of the Wechsler Intelligence Scales for Children–Third Edition (WISC-III, Wechsler, 1992, Greek version by Georgas et al., 1997). We asked the following questions:

Research question 1. Is performance in VIQ and PIQ subscales similar across monolingual and bilingual children with DLD?

Research question 2. Are there discrete IQ profiles in children with DLD that reflect weaknesses or/and strengths in VIQ and PIQ, which are specific to monolingual and bilingual participants? Do children's age, SES (maternal education, paternal education and household income), language ability and bilingual exposure metrics correlate with the children's performances in the VIQ and PIQ subscales of the tool?

Research question 3. Does children's maternal education affect VIQ/PIQ profiles in monolingual and bilingual children with DLD?

Methods

Participants

The participants included in the study were 234 children with DLD aged 6;0–14;9 years (M=10;6, SD=2.5; 60 females; the semicolon signifying the exact age in years and months). The children were recruited from public diagnostic centers for educational and counseling support in the region of Thessaly in central Greece. The specific centers have been officially authorized since 2003 by the Greek state to issue diagnoses of language disorders to school-aged children attending public schools in Greece. Assessment and evaluation procedures in the centers are conducted by multidisciplinary teams composed of speech and language therapists, clinical psychologists, special education teachers, social workers, child psychiatrists and developmental pediatricians specialized to diagnose DLD and officially licensed to do so by the Greek Ministry of Education.

According to DSM-5 criteria (American Psychiatric Association, 2013), a diagnosis of DLD was excluded by the presence of any hearing loss, autism, obvious neurological dysfunctions or motor deficits. The diagnosis of DLD was supported by questionnaires, language and neuropsychological testing. More specifically, parental questionnaires and language unit class teachers' reports underscored considerable delays in the children's language development, as well as expressive and receptive language difficulties in both the written and oral modality (Leonard, 1998, 2014). Teachers' observations about the children's language difficulties included limited use of structurally complex utterances, lexical retrieval difficulties, slow speech rate and reduced comprehension of complex and lengthy speech. Furthermore, the PIQ index of the children fell within the normal range, i.e., PIQ > 70 (Botting, 2005; Conti-Ramsden et al., 2012). Bilingual children with DLD attended mainstream classes in Greece and were all Albanian-Greek born to mixed marriages, so they were simultaneous bilinguals. Parental questionnaires underscored considerable delays in children's both languages.

Parents of bilingual children also completed a questionnaire (Andreou, 2021; Torregrossa et al., 2021) that measured (a) children's language experience, and more specifically, current language input–output in each language, i.e., Albanian and Greek, and (b) the proportion of oral language input by the child's father and mother in each language prior to schooling, which was termed as home language history. More specifically, the current language use index measures current language use and exposure to each or both languages in various contexts (e.g. conversations, helping the child during homework, speaking on the phone) with family members (i.e. mother, father, siblings, grandparents and other relatives) and friends. Interlocutors were equally weighted while scoring the answers (e.g. "Grandparents/friends/relatives talk to the child, or the child talks to them mostly in Greek/mostly in Albanian/in Greek and Albanian equally"). Home language history, on the other hand, measures the bilingual child's language exposure from birth up to the age of 4 years, i.e. before bilingual children are immersed in monolingual/monoliterate Greek education. The component of the questionnaire that measures home language history includes questions about the languages that the child heard and used when orally communicating with her/his parents, siblings, grandparents, relatives, and friends before attending kindergarten, and its scoring is similar to that in current language use. As such, the current language use index in the present study provided us with a rather global language experience measure, while home language history reflected children's past language experience before entering preschool education. We should note that each question of the questionnaire targeted both oral language use and exposure to Greek and Albanian, so quantifying language use and exposure individually was not applicable.

In Table 1, language experience percentages show current language use and home language history in Greek, while the remaining percentages show corresponding metrics in Albanian. The current language use and home language history percentages in Greek were slightly higher than the corresponding rates in Albanian (Table 1).

Monolingual and bilingual children with DLD were also administered two language screening tests in Greek, namely, an expressive vocabulary standardized for Greek-speaking TD monolingual children (Vogindroukas et al., 2009, adaptation from Renfrew, 1997) and a sentence repetition test (Stavrakaki & Tsimpli, 2000) with norms for 3-to-7 year-old TD monolingual Greek-speaking children. There are currently no normed tests for expressive vocabulary and sentence repetition in Albanian, so it was not possible to directly compare Albanian-Greek DLD children to TD bilingual peers. However, validated data of age-matched TD simultaneous Albanian-Greek children that have been assessed on the same expressive vocabulary test (Andreou, 2021) and a similar sentence repetition test (Prentza et al., 2022) showed that the bilingual children with DLD in the current study have scored at least two standard deviations below the mean scores of TD bilingual peers (see Table 1), further suggesting that the language ability of the bilingual children that have participated in the current study was impaired.

Socioeconomic Measures: Maternal Education, Paternal Education, and Family Income

Following classifications of parental educational level in previous research (e.g., Rashid et al., 2020; van Ansem et al., 2014), both maternal and paternal education in the current study served as individual-level proxies for low- (education < 7 years), medium- (education between 7 and 9 years) and high parental education groups (education > 10 years). Education cut-off points are based on the Greek educational system, where six years correspond to primary school education, nine years correspond to lower secondary school education, and ten years indicate upper high school education. Besides education, yearly family income also served as an individual-level measure of SES: upper limit 15,000 euros corresponding to low SES, coded as 1; 15,000–25,000 euros corresponding to medium SES, coded as 2; and 25,000–35,000 euros corresponding to high SES, coded as 3. The three-level categorization was based on the Organisation for Economic Co-operation and Development (OECD) economic survey reports for family incomes in Greece between 2018 and 2021 (OECD, 2018, 2019, 2020,

Table 1 Participants' characteristics – mean (SD) and minimum-maximum values

	MO-DLD ($n=109$)	BI-DLD ($n=125$)	Wilcoxon signed rank test*	
			W	*p*
Age (years; months)	10;6 (2.5) 6–14;9	10;6 (2.4) 6;2–14;9	6837.5	0.962
maternal education (years of education of the mother)	5.61 (1.9) 2–12	6.83 (1.8) 3–12	4257	**<0.001**
paternal education (years of education of the father)	6.32 (1.5) 2–13	7.15 (1.9) 5–13	5170	**<0.001**
Household income (yearly family income)	1.04 (0.2) 1–2	1.05 (0.3) 1–3	6840.5	**0.865**
VIQ	71.0 (11.7) 43–94	74.8 (6.2) 60–93	5992.5	0.111
PIQ	88.5 (10.2) 71–121	94.3 (9.2) 77–116	4368.5	**<0.001**
FSIQ	80.0 (9.8) 60–104	84.8 (6.7) 71–101	4931.5	**<0.001**
Expressive vocabulary (max. score: 50)	33.9 (5.3) 19–44 Normed vocabulary age equivalent: 7;5	29.4 (4.8) 19–39 Normed vocabulary age equivalent: 6;8	10,146	**<0.001**
Expressive vocabulary mean of TD Albanian-Greek children		37.2 (3.6)		
SR (max. score: 30)	21.3 (4.8) 13–30	18.1 (5.3) 6–28	8846	**<0.001**
SR mean of TD Albanian-Greek children		27.82 (4.4)		
% Current Greek use		58.4 (13.8) 29–81		
% Home language (Greek) history		50.9 (16.8) 20–86		

MO-DLD monolingual children with DLD, *BI-DLD* bilingual children with DLD, *VIQ* Verbal IQ, *PIQ* Performance IQ, *SR* sentence repetition, *TD* typically-developing, *max.* maximum, *n* number. Normality of the distributions was assessed using the Shapiro–Wilk test with a significance level of $\alpha=0.05$. Since data distribution was not normal (Shapiro-Wilk test), non-parametric tests were used. Values in bold indicate significant effects

2021), which was the period when the data of the current study was collected.

We should note that the study participants and their families came from an agricultural, mountainous region in central Greece facing considerable socioeconomic disparities, which are related, first, to the geographical location that limits access to diagnostic services and early treatment, and, second, to the high rates of unemployment in the particular region (Herod et al., 2021). In fact, the particular region is a high poverty district with families reporting incomes below the federal poverty standards and less than a primary school level of parent education (Anthopoulou et al., 2019; Peristeri & Andreou, 2024). As already mentioned, bilingual children with DLD were all Albanian-Greek born to mixed marriages, with an Albanian mother. The region of Thessaly, which was the locus of fieldwork in the current study, is known as a major agricultural center in Greece with a population of 700,00 inhabitants. This is one of the reasons why it attracts Albanian immigrants, as many come to Thessaly to work in farming, and to take advantage of the cost of living which is relatively more affordable in comparison to urban regions in Greece (Vullnetari, 2012). The majority of the Albanian mothers of the bilingual DLD children in the current study were young women (under 32 years) at the time of testing. Most had dropped primary school education, and few had finished lower or upper secondary education in their home country (Albania). Most Greek fathers, on the other hand, had finished primary school education in Greece, and few had finished a vocational training school after graduating from upper secondary schools. The majority of the Albanian mothers was employed in the agricultural sector at the time of testing, or as domestic nurses for elderly people. Also, a dominant social trait characterizing the profile of Albanian women immigrants in Greece, including those living in Thessaly, was their aspirations about their children's educational outcomes (Gkaintartzi et al., 2014).

Experimental Tasks

WISC-III. Every child was tested with the Greek version of WISC-III (Georgas et al., 1997). The WISC-III consists

of 12 subtests, six pertaining to VIQ and six to PIQ (for a description of each subtest of WISC-III and the skill(s) that they assessed see the Table 6). The standardized scores of each subtest range from 1 to 19, and classify the performance as high (> 10), normal (8–10), and below normal range (< 8). Besides standardized scores in each test of WISC-III's VIQ and PIQ subscales, the children's general VIQ, PIQ and Full Scale IQ (FSIQ) indexes were recorded.

Expressive vocabulary task (Vogindroukas et al., 2009, adaptation from Renfrew, 1997). The test includes 50 black-and-white pictures of objects that each child had to name. The maximum score is 50.

Sentence repetition task (Diagnostic Verbal Intelligence Quotient/DVIQ, Stavrakaki & Tsimpli, 2000). The test includes ten sentences of various degrees of structural complexity. The child earned three points for each sentence being repeated correctly, two points and a single point in case of one and two errors, respectively. If more than two errors were committed, the score was zero points. The maximum score is 30 points.

Each participant was administered WISC-III by a licensed Greek-speaking monolingual female psychologist in a quiet room of the diagnostic center in a single session that lasted approximately 2 h including breaks. In a second session, children were administered the expressive vocabulary and sentence repetition tests by the first author. The study protocol complied with the ethical standards of the relevant national and institutional committees on human experimentation and with the Helsinki Declaration of 1975, as revised in 2008. All study procedures were approved by the Institutional review board (IRB) and Ethics Committee of the Aristotle University of Thessaloniki, Greece (IRB protocol number: 39928/20-02-2018) University of xxxxx (IRB protocol number: xxxxx/20-02-2018). Enrollment of the children was consecutive from 2018 to 2021. The privacy rights of the participants have been observed and parental written consent was required for participation in the study.

Data Analysis

We first present the sociodemographic characteristics, i.e., age, maternal education, paternal education, and income of our population with DLD, and ran comparisons between MO-DLD and BI-DLD children on these characteristics, as well as on their performances in expressive vocabulary and sentence repetition as proxies for the children's language ability, and the VIQ and PIQ scales of the WISC tool. Next, to answer the study's first research question, i.e., whether performances in the VIQ and PIQ subscales would be similar across MO-DLD and BI-DLD children, we computed mean standardized scores in each subtest for each group, and used WISC-III's cut-off points to characterize their performances: > 10 for high performance; 8–10 for normal range performance; < 8 for below normal range performance. To address the second research question about identifying discrete IQ phenotypical profiles within the 234 children with DLD, a cluster analysis was conducted on the data of the 12 subtests of WISC-III. The cluster analysis was run through a hard clustering method (K-means clustering) whereby each data point is assigned to their closest centroid, based on the Euclidean distance between the object and the centroid (MacQueen, 1967; Kassambara, 2017). Prior to clustering, all subtest scores were z-standardized to ensure comparability across scales. The optimal number of clusters was determined using a combination of indices provided by the *NbClust* package: according to the majority rule, results supported the selection of a 3-cluster solution. The algorithm was run with *nstart = 10* to reduce sensitivity to initialization, and the final solution selected was the one with the lowest total within-cluster sum of squares. Pairwise Euclidean distances between the final centroids were calculated to assess the degree of separation between clusters. To aid visualization of the clusters, we performed a Principal Component Analysis (PCA) on the standardized subtest scores; PCA was conducted solely for visualization purposes. The two principal components used in Fig. 2 together accounted for 49% of the total variance (PC1 = 37%, PC2 = 12%).

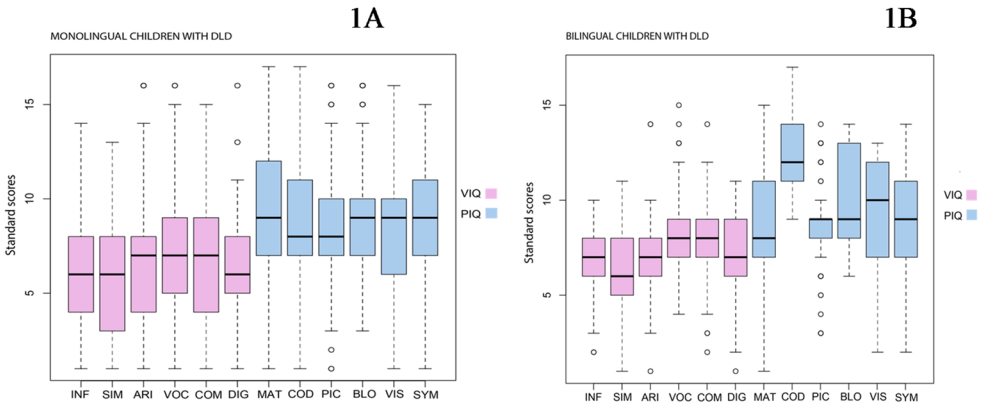

Fig. 1 Standardized scores on WISC-III subtests for the monolingual and bilingual group with developmental language disorder

Since bilingual children with DLD did not differ from their monolingual peers on age, we conducted the cluster analysis on the totality of the participants, i.e., 234 children. We next applied regression models to investigate whether IQ would depend on the predictor variables, namely, maternal and paternal education, household income, and age, and whether sentence repetition, expressive vocabulary, and bilingual exposure, i.e., current language use, and home language history in Greek, would be related to IQ scores in the clusters. Finally, to address the third research question and investigate the relation between bilingualism and maternal education, and their potentially joint impact on DLD children's IQ scores, we investigated whether bilingualism might have acted as a mediator factor between IQ scores and maternal education. This analysis was run only on maternal education because it was the only measure returning significant effects on children's cognitive abilities, both VIQ and PIQ. To this end, we decided to run a mediation analysis on the bilingual children only, using the scores obtained for current language (Greek) use and home language history (in Greek). All statistical analyses were conducted with the R-studio version 4.2.2 (R Core Team, 2017). Cluster analysis was performed with the *factoextra* (Kassambara & Mundt, 2020), *cluster* (Maechler et al., 2023) and *NbClust* (Charrad et al., 2014) packages, regression analysis was conducted with the *lme4* (Bates et al., 2015) package, and mediation analysis with the *lavaan* (Rosseel, 2012) package.

Table 2 Standardized scores on WISC-III subtests for MO-DLD and BI-DLD groups – mean (SD) and minimum-maximum values

		MO-DLD ($n=109$)	BI-DLD ($n=125$)
VIQ	Information (INF)	6 (3) 1–14	6.7 (1.6) 2–10
	Similarities (SIM)	5.8 (3.2) 1–13	6.3 (1.7) 1–11
	Arithmetic (ARI)	6.9 (3.4) 1–16	6.9 (1.9) 1–14
	Vocabulary (VOC)	7.3 (3.6) 1–16	8 (2.4) 4–15
	Comprehension (COM)	6.7 (3.4) 1–15	8 (1.5) 2–14
	Digit span (DIG)	6.2 (2.6) 1–16	7.1 (2.4) 1–11
PIQ	Matrix reasoning (MAT)	8.8 (3.5) 1–17	8.6 (3.1) 1–15
	Coding (COD)	8.6 (3.2) 1–17	12.4 (2.1) 9–17
	Picture completion (PIC)	8.4 (3.2) 1–16	8.8 (2.3) 3–14
	Block design (BLO)	9.5 (2.9) 3–16	10.2 (2.4) 6–14
	Visual puzzles (VIS)	8.6 (3.6) 1–16	9.2 (2.8) 2–13
	Symbols (SYM)	8.7 (3.2) 1–15	8.9 (2.5) 2–14

MO-DLD monolingual children with DLD, *BI-DLD* bilingual children with DLD, *VIQ* Verbal IQ, *PIQ* Performance IQ, *n* number

Results

The main characteristics of our population with DLD are presented in Table 1. No difference emerged between monolingual and bilingual children with DLD on age and household income, while maternal and paternal education were significantly higher in the bilingual group than in monolinguals. Furthermore, bilingual children with DLD performed in line with their monolingual peers on the VIQ index, while they outperformed them on PIQ and FSIQ index. Besides the mean expressive vocabulary and sentence repetition raw scores, and in order to use the tests' standardized scores, we have further calculated the expressive vocabulary age equivalents. BI-DLD children performed significantly lower than their monolingual peers on both expressive vocabulary and sentence repetition. Furthermore, as one can see in Table 1, there was at least a 3- and a 4-year discrepancy between the chronological and expressive vocabulary ages for the MO-DLD and BI-DLD groups, respectively, with the mean chronological age being greater than the expressive vocabulary age across both groups. Furthermore, the mean scores in expressive vocabulary and sentence repetition of TD bilingual peers which have been derived from Andreou (2021), and Prentza and colleagues (2022), respectively, show that the bilingual children with DLD in the current study have scored at least two standard deviations below the mean scores of TD bilingual peers. Both the expressive vocabulary age equivalent and the performance gaps noticed between the bilingual DLD children and the validated TD bilingual data from Andreou (2021) and Prentza et al. (2022) in expressive vocabulary and sentence repetition, respectively, are suggestive of language impairment in both groups.

Research Question 1. Is Performance in VIQ and PIQ Subscales Similar Across Monolingual and Bilingual Children with DLD?

Table 2 illustrates the groups' mean scores on the WISC-III subtests (see also Fig. 1A, B visualizing the scores for the MO-DLD and BI-DLD group, respectively). Both groups showed normal mean scores in all the tests of the PIQ index. Monolinguals, as a group, systematically scored below the cut-off of performance in the normal range, i.e., < 8 standard scores, on all subtests of the VIQ index, while bilinguals, as a group, exhibited performance in the normal

range on two out of the six subtests of VIQ: Vocabulary and Comprehension.

Importantly, the range of scores for each of the WISC-III subtests reveals that there were children in both groups performing below and above-average, with the exception of the Coding test where BI-DLD children seemed to achieve average/above-average scores. This heterogeneity emphasizes the necessity of thoroughly examining IQ scores in both groups to see how many discrete profiles of cognitive (dis)abilities we can identify in our dataset, and whether bilingual and monolingual children are grouped into the same profiles of (dis)abilities. Following this line, we investigated the performance of MO-DLD and BI-DLD children on WISC-III through the use of cluster analysis, an integrated machine learning technique, to determine if any identifiable phenotypical profiles would emerge.

Research Question 2. Are There Discrete IQ Profiles in Children With DLD That Reflect Weaknesses or/and Strengths in VIQ and PIQ, which are Specific to Monolingual and Bilingual Participants? Do Children's Age, SES (Measured via Maternal Education, Paternal Education and Household Income), Language Ability and Bilingual Exposure Metrics Correlate With the Children's Performances in the VIQ and PIQ Subscales of the Tool?

A function, independent of the K-means algorithm, determined the optimal number of clusters using different methods, e.g., *Average silhouette* (see Kaufman & Rousseeuw, 2009, Kassambara, 2017). The optimal number of clusters was automatically estimated to be three. Crucially, the *NbClust* function, which provides 30 indices for determining the number of clusters and proposes to use the best clustering scheme from the different results obtained by varying all combinations of number of clusters, distance measures, and clustering methods, returned the same result. We, therefore, ran the visualization plot algorithm of our model-based cluster, with $k=3$. Distributions are represented in Fig. 2. The characteristics of the centroid mean of each cluster are reported in Table 3; these characteristics allowed us to identify and describe the three clusters. We also report Euclidean distances between the cluster centroids in Table 7. They indicated clear separation among the three profiles: Cluster 1 vs. Cluster 2 = 8.99; Cluster 1 vs. Cluster 3 = 9.01; and Cluster 2 vs. Cluster 3 = 16.25. The largest separation was observed between Clusters 2 and 3, suggesting that these two groups showed the most divergent cognitive performance patterns across the 12 WISC-III subtests (see Norambuena et al.'s (2022) study also yielding three clusters identifying discrete cognitive profiles in children with DLD).

Two profiles showed "homogeneous" abilities on both VIQ and PIQ scores: Cluster 2 displayed average/above-average VIQ and PIQ scores, while Cluster 3 showed low VIQ and PIQ scores. Cluster 1, on the other hand, showed discrepant abilities between PIQ average and VIQ low; crucially, this cluster constituted the largest cluster of our

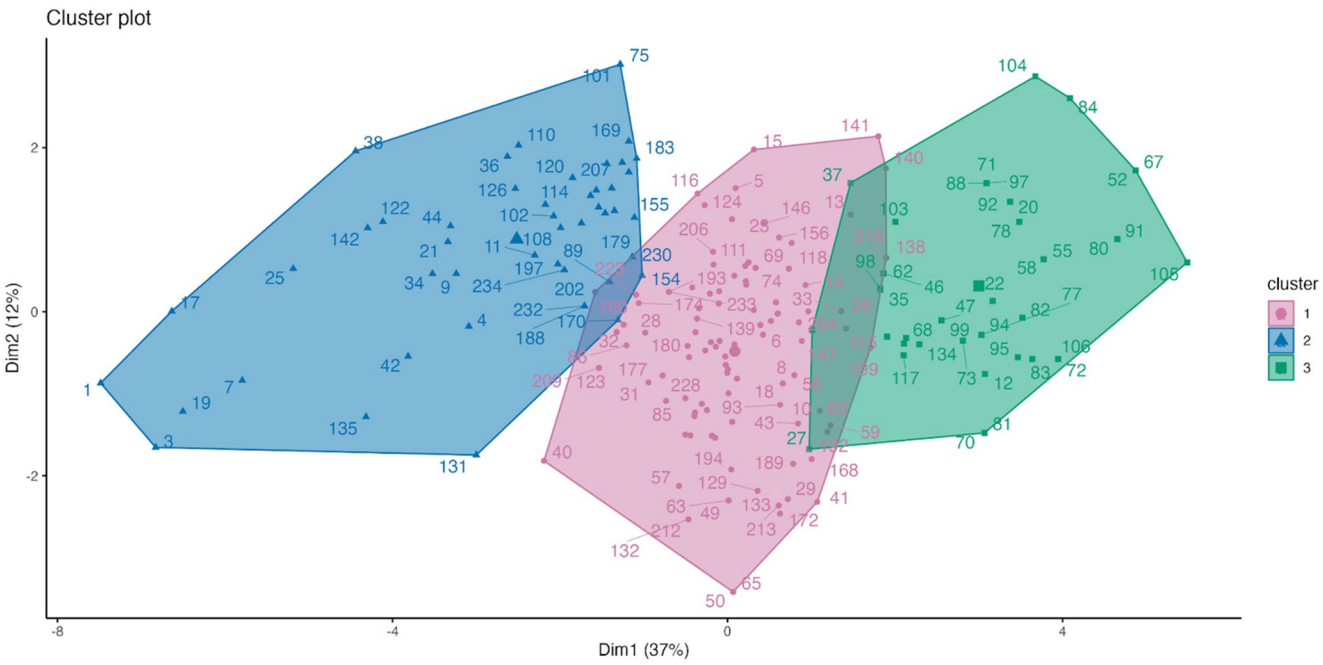

Fig. 2 Cluster analysis (K-means) identifying cognitive profiles in monolingual and bilingual children with developmental language disorder. The plot displays the first two principal components derived from a principal component analysis (PCA) performed on the 12 standardized WISC-III subtest scores, used solely for visualization of the cluster separation

Table 3 Distribution of the clusters and descriptive stats (bold scores are below the threshold)

		Cluster 1 ($n=133$)	Cluster 2 ($n=57$)	Cluster 3 ($n=44$)
VIQ	Information	6.67	7.94	3.68
	Similarities	6.65	7.17	3.11
	Arithmetic	6.76	8.73	5.25
	Vocabulary	7.89	9.93	4.45
	Comprehension	7.53	9.10	5.04
	Digits	7.04	7.51	4.77
PIQ	Matrix	**7.95**	12.38	**6.45**
	Coding	11	12.79	**6.77**
	Picture concepts	8.49	11	**6.11**
	Block Design	8.97	13.40	8.07
	Visual puzzles	8.16	12.56	**6.82**
	Symbols	9.27	9.42	**6.86**
	Cluster	Average PIQ cognitive abilities/impaired VIQ	High PIQ abilities and average VIQ abilities	Low cognitive abilities (both verbal and nonverbal)
	n of children	133	57	44
	n of MO-DLD	50 (45.9%)	20 (18.3%)	39 (35.8%)
	n of BI-DLD	83 (66.4%)	37 (29.6%)	5 (4%)

MO-DLD monolingual children with DLD, *BI-DLD* bilingual children with DLD, *VIQ* Verbal IQ, *PIQ* Performance IQ, *n* number. Values in bold indicate performances below the normal range (<8)

sample ($n=133$ children). No profile showing low PIQ and average/above-average VIQ emerged. Individual results confirmed this result: except for one participant, no child showed impaired performance on the PIQ, in presence of normal abilities in the VIQ. Looking at the prevalence of monolingual and bilingual children across the three clusters, while monolinguals were distributed across Cluster 1 ($n=50$), 2 ($n=20$), and 3 ($n=39$), bilingual children distributed only in Clusters 1 ($n=83$) and 2 ($n=37$). Indeed, bilingual children were almost absent from Cluster 3 ($n=5$), which was the cluster displaying impaired PIQ and VIQ abilities overall. Also, BI-DLD children constituted almost the double of their monolingual peers in Cluster 1 and 2. In other words, BI-DLD children seemed to generally show higher IQ scores than their monolingual peers.

To further explore whether extra-cognitive factors, such as maternal education, paternal education and household income, age, language ability, i.e., sentence repetition and expressive vocabulary, and scores of bilingual exposure for the bilingual children, i.e., current language use and home language history, would have an impact on the scores obtained by the children with DLD in the monolingual and bilingual groups, we ran multiple linear regression analysis on VIQ and PIQ indexes (see Table 4). The results indicated that only maternal education had a significant effect on both VIQ (p =.005) and PIQ (p =.047) for the MO-DLD group; as the VIQ/PIQ score increased, maternal education scores tended to increase as well. No other effect emerged. In the bilingual group with DLD, no significant effect was found in either VIQ or PIQ scores.[1]

Research Question 3. Does Children's Maternal Education Affect VIQ/PIQ Profiles in Monolingual and Bilingual Children With DLD?

When we plot the distribution of monolingual and bilingual children in the three clusters based on their maternal education scores (Fig. 3), we can see that monolingual children with the lowest maternal education scores were mainly grouped in Cluster 3, which was the profile showing impaired cognitive abilities both in PIQ and VIQ (see Table 3).

These results seem to confirm the effect of maternal education found in the regression models for monolingual children and the absence of such effect in the bilingual group with DLD, but at the same time it raises a more general question regarding the possible boosting effect of maternal education on the intellectual abilities of the bilingual group with DLD. In fact, bilingual children might achieve higher IQ scores just because they had higher maternal education scores than their monolingual peers. Thus, to understand whether being bilingual can increase per se the chance of obtaining higher scores in IQ, we decided to match MO-DLD and BI-DLD children on maternal education - regardless of the clusters they were assigned to - and compare

[1] Pairwise correlations among all predictors for the monolingual (MO) and bilingual (BI) groups indicated that maternal and paternal education were significantly correlated in both groups (MO-DLD: r=.82, 95% CI [0.75, 0.88], p <.001; BI-DLD: r=.83, 95% CI [0.76, 0.87], p <.001), as were sentence repetition and expressive vocabulary (MO-DLD: r=.60, 95% CI [0.47, 0.71], p <.001; BI-DLD: r=.63, 95% CI [0.51, 0.72], p <.001). A weak correlation emerged between Home language (Greek) history and Current language (Greek) use in the BI-DLD group (r=.18, 95% CI [0.00, 0.34], p =.039). When we assessed whether multicollinearity posed a problem for the regression analyses, examining Variance Inflation Factors (VIFs) for all predictors in each model, results showed that all VIF values were within acceptable limits (VIFs in all models<5).

Table 4 Summary of regression analyses on VIQ and PIQ for monolingual and bilingual children with DLD

MO-DLD – VIQ				
	Estimate	SE	t-value	*p*
Intercept (VIQ)	58.777	9.346	6.288	<0.001
Maternal education	2.923	1.022	2.860	**0.005**
Paternal education	−1.354	1.267	−1.068	0.287
Household income	0.999	6.022	0.166	0.868
Age	−1.608	0.851	−1.890	0.061
SR	0.006	0.345	0.018	0.985
Expressive vocabulary	0.599	0.353	1.693	0.093
MO-DLD – PIQ				
	Estimate	SE	t-value	p
Intercept (PIQ)	76.896	8.743	9.075	<0.001
Maternal education	1.953	0.926	2.109	**0.047**
Paternal education	−0.391	1.149	−0.341	0.733
Household income	−0.183	5.459	−0.034	0.973
Age	−0.044	0.771	−0.058	0.953
SR	−0.589	0.313	−1.882	0.062
Expressive vocabulary	0.481	0.320	1.501	0.136
BI-DLD – VIQ				
	Estimate	SE	t-value	p
Intercept (VIQ)	70.358	5.410	13.003	<0.001
Maternal education	0.356	0.542	0.658	0.512
Paternal education	0.179	0.520	0.344	0.732
Household income	−1.731	1.996	−0.867	0.388
Age	−0.374	0.749	−0.500	0.618
SR	−0.091	0.150	−0.610	0.543
Expressive vocabulary	0.352	0.332	1.060	0.291
Current language use (Greek)	−0.049	0.033	−1.461	0.147
Home language history (Greek)	0.005	0.042	0.134	0.894
BI-DLD – PIQ				
	Estimate	SE	t-value	p
Intercept (PIQ)	79.127	7.999	9.891	<0.001
Maternal education	1.035	0.802	1.291	0.199
Paternal education	−0.505	0.769	−0.657	0.512
Household income	4.269	2.952	1.446	0.151
Age	−0.025	1.107	−0.022	0.821
SR	−0.301	0.221	−1.359	0.177
Expressive vocabulary	0.411	0.491	0.838	0.404
Current language use (Greek)	0.066	0.050	1.334	0.185
Home language history (Greek)	−0.003	0.063	−0.048	0.962

MO-DLD monolingual children with DLD, *BI-DLD* bilingual children with DLD, *SR* sentence repetition, *VIQ* Verbal IQ, *PIQ* Performance IQ, *n* number. Values in bold indicate significant effects

their respective performances on each subtest of the WISC-III. Three groups were created: low maternal education, medium maternal education, and high maternal education. The low group included children whose maternal education was <7 years; the medium group included children whose maternal education was between 7 and 9 years; and the high group included children whose maternal education was >10 years. A total of 178 children (94 MO-DLD children and 84 BI-DLD children) constituted the low group, and 47 children (13 MO-DLD children and 34 BI-DLD children) comprised the medium group. Due to the low number of children in the high group ($n=9$), these children were excluded from the following analysis. We should note that the difference in mean years of maternal education between the MO-DLD-low and the BI-DLD-low group was significant (for the MO-DLD low group: mean=5.04; SD=1.3; min=2, max=6; for the BI-DLD low group: mean=5.76; SD=0.7; min=3, max=6), with the former group showing fewer years of school attendance than the latter, ($W=2670$, p <.001). On the other hand, no significant difference ($W=250$, p =.356) in years of education was observed between the MO-DLD and the BI-DLD children falling in the medium range (for the MO-DLD Medium group: mean=8.76; SD=0.6; min=7, max=9; for the BI-DLD Medium group: mean=8.47; SD=0.9; min=7, max=9). To investigate IQ differences between the MO-DLD-low and the BI-DLD-low group (see Table 8 for descriptive results), a MANOVA analysis for inter-group comparisons was used (see Table 5). Bilingualism emerged as a contributing factor only in the low group, in which bilingual children performed significantly better than monolingual maternal education-matched children on almost all subtests - except for Symbols and the Vocabulary subtest - while the effects that were found in the medium groups were in favor of the MO-DLD children – except for the Coding subtest where bilinguals outperformed their monolingual peers.

We therefore decided to run a mediation analysis to see whether bilingualism – evaluated via the current Greek language use and home language history in Greek measurements - might have acted as a mediating factor between the contributing variable of maternal education, and the VIQ and PIQ scores in the low group. We concentrated our analysis only on bilingual children. The hypothesized mediation models (see Fig. 4 below; and the Table 9) were tested in a single model using a bootstrapping approach to assess the significance of the indirect effects at differing levels of the moderator (Hayes, 2013).

The results of the mediation analysis on VIQ showed a total effect of maternal education (*estimate*=1.983, *SE* = 0.769, *z-value*=2.579, p =.010), and a significant indirect effect of maternal education on VIQ through home language (Greek) history (*estimate*=−0.527, *SE* = 0.271, *z-value* = −1.942, p =.052); no indirect effect of current language (Greek) use (*estimate*=−0.014, *SE* = 0.121, *z-value*=−0.113, p =.910) emerged. Regarding PIQ, results showed a significant total effect of maternal education (*estimate*=3.716, *SE*=1.141, *z-value*=3.258, p =.001), but no indirect effect of maternal education on PIQ through current

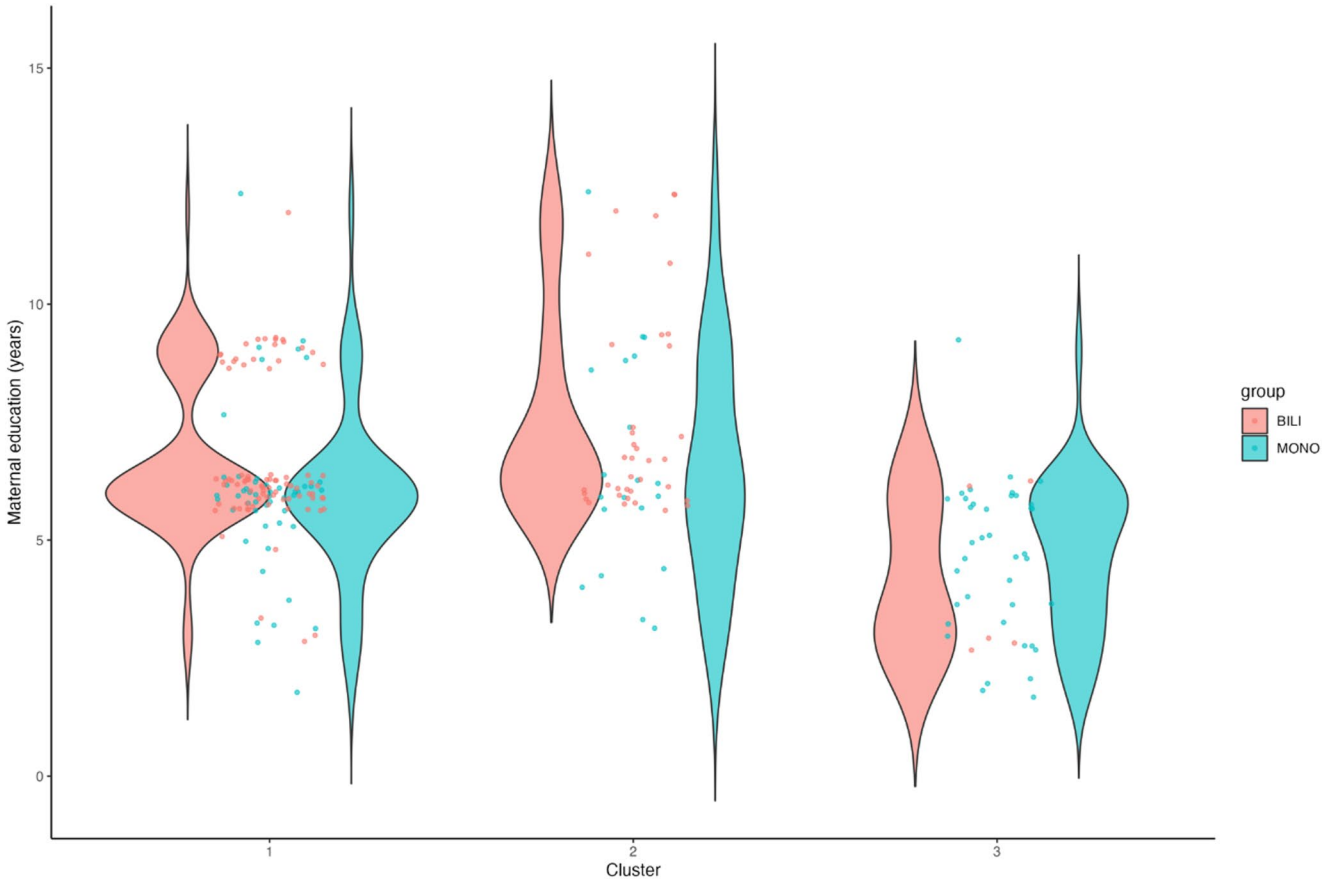

Fig. 3 Distribution of monolingual (MONO) and bilingual (BILI) children with developmental language disorder in the three clusters on the basis of their maternal education scores

Table 5 Differences between monolingual and bilingual children with DLD in each maternal education group on WISC subtests in the maternal education-low and maternal education-medium groups

		Low maternal education	Medium maternal education
VIQ	Information	F (1, 176) = 4.91, p = **.027**	F (1, 45) = 4.03, p = .050
	Similarities	F (1, 176) = 3.81, p = .052	F (1, 45) = 1.44, p = .235
	Arithmetic	F (1, 176) = 2.89, p = .090	F (1, 45) = 20.07, p **<.001***
	Vocabulary	F (1, 176) = 0.51, p = .475	F (1, 45) = 1.30, p = .260
	Comprehension	F (1, 176) = 9.97, p = **.001**	F (1, 45) = 0.48, p = .488
	Digits	F (1, 176) = 19.62, p**<.001**	F (1, 45) = 7.08, p = **.010 ***
PIQ	Matrix	F (1, 176) = 3.33, p = .069	F (1, 45) = 0.08, p = .771
	Coding	F (1, 176) = 94.46, p**<.001**	F (1, 45) = 16.45, p **<.001**
	Picture concepts	F (1, 176) = 3.28, p = .071	F (1, 45) = 14.09, p**<0.001***
	Block design	F (1, 176) = 4.94, p = **.027**	F (1, 45) = 0.09, p = .758
	Visual puzzles	F (1, 176) = 4.80, p = **.029**	F (1, 45) = 7.09, p = **.010***
	Symbols	F (1, 176) = 0, p = .997	F (1, 45) = 0.76, p = .385

Significant differences are in bold; * marks the comparison that resulted in higher scores for the mono-DLD group

language (Greek) use (*estimate* = 0.000, *SE* = 0.211, *z-value* = 0.002, p = .998), or home language (Greek) history (*estimate* = 0.361, *SE* = 0.434, *z-value* = 0.833, p = .405).

Discussion

The current study has examined performances in the VIQ and PIQ tests of WISC-III in monolingual Greek-speaking and bilingual Albanian-Greek (-dominant)-speaking children with DLD. Previous research (e.g., Botting, 2005, Conti-Ramsden et al., 2012) evaluating intellectual functioning in children with DLD has focused on monolingual

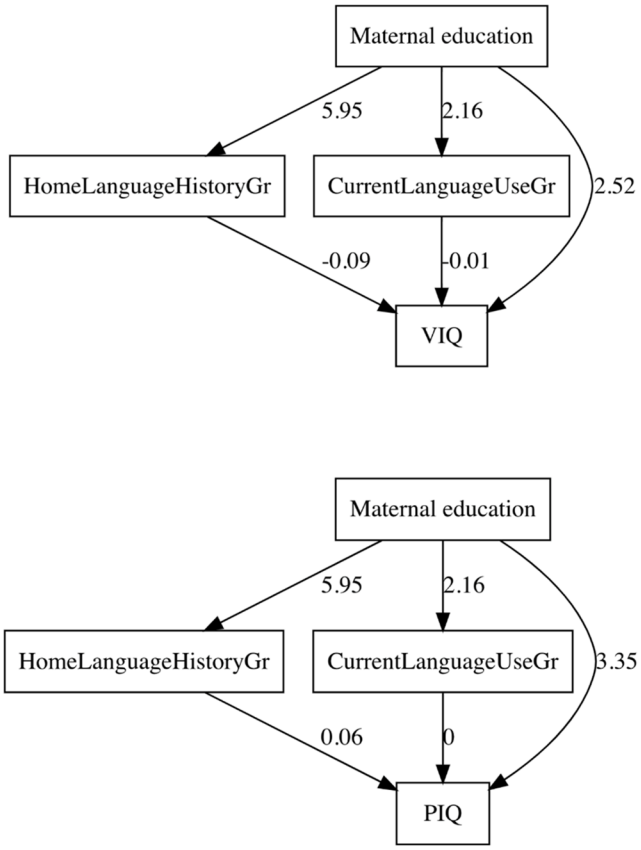

Fig. 4 Mediation analyses on verbal IQ and performance IQ. *Gr* Greek, *VIQ* verbal IQ, *PIQ* performance IQ

children with DLD only, as well as minimally dimensional measures of IQ, such as VIQ, PIQ and FSIQ indexes. The current study has focused on bilingual along with monolingual children with DLD and, thus, provides a high dimensional space to evaluate differences between the two groups in individual components of the VIQ and PIQ scales. Furthermore, in this study we applied IQ subtyping to yield better insight into the individual differences, namely, socioeconomic characteristics (maternal and paternal education, family income), language experience, language ability and age, driving group differences in VIQ and PIQ performances in WISC-III. To this aim we examined whether children with DLD could be split into discrete IQ phenotypical subtypes using an unsupervised data-driven stratification approach applied to children's IQ metrics. In summary: the bilingual children with DLD exhibited 'normalized' performance in two VIQ tests, specifically in Vocabulary and Comprehension, in contrast to the monolingual group with DLD which scored below normal range in VIQ tests. Moreover, the unsupervised clustering analysis stratifying children with DLD into discrete subtypes showed that bilingual children with DLD were more likely to exhibit unaffected skills in the PIQ domain as compared to their monolingual peers. Importantly, our study also revealed that bilingualism and maternal education, but not paternal education and family income, had an inter-dependent impact on the children's IQ performance. More specifically, maternal education and bilingualism functioned as two complementary components of DLD children's intellectual functioning, since positive effects of bilingualism on DLD children's VIQ and PIQ performance was only observed for children living in families where the mother has a lower level of education, while boosts of VIQ were especially maximized for those children with high language input in the two languages before schooling.

Specifically, the first research question was to investigate whether the two groups of monolingual and bilingual children with DLD would perform similarly across the VIQ and PIQ tests of WISC-III. We found that bilingual children with DLD showed a slight advantage over their monolingual peers in two out of the six tests of the VIQ scale. Specifically, the bilingual group tended to score within normal range in Vocabulary and Comprehension, while the mean score of the monolinguals was below the cut-off of normal performance in the respective tests. While we cannot tell which specific mechanisms have boosted the performance of the bilingual children with DLD in the two VIQ tests of WISC-III, this advantage seems to be mainly metacognitive in nature. Specifically, the Vocabulary subscale in WISC-III is a word definition test that measures word knowledge and verb concept formation, both being characterized as being metalinguistic skills (Benelli et al., 2006; Karmiloff-Smith et al., 1996). Besides their difficulties with language mechanics, including syntax and morphology, children with DLD have been reported to exhibit deficits in metalinguistic awareness (Davies et al., 2023; Dosi & Gavriilidou, 2020; Smith-Lock, 1995). Bilingualism has been often reported to boost growth of general metalinguistic abilities in TD children (e.g., Bialystok & Majumder, 1998, Diaz & Farrar, 2018), further implying that bilingual DLD children's better performance in Vocabulary may have been rooted in the group's higher ability to reflect upon the conceptual and semantic aspects of the words as compared to their monolingual peers.

Similarly, bilingual DLD children's superior performance than monolinguals in Comprehension suggests that the bilingual group was more competent to judge and explain social situations, actions, or activities than their monolingual peers. WISC-III's Comprehension VIQ test measures practical judgment in social contexts and common-sense knowledge, as well as the individual's level of social maturation and moral judgment of various scenarios. Though research in DLD has so far predominantly focused on language abilities, there is evidence that a non-negligible portion of individuals with DLD also struggles with higher-order social

reasoning, such as recognizing transgressions of social norms (Winstanley et al., 2018), or attributing false beliefs to other individuals (Andrés-Roqueta & Katsos, 2020; Durrleman & Delage, 2020; Durrleman et al., 2022). Bilingual DLD children's superior performance in Comprehension, however, should be interpreted with caution. The fact that the performance range in both VIQ tests of WISC-III also included scores which were below the normal range (see Table 2) implies that the beneficial impact of bilingualism was not generalizable to all the participants with DLD. Notably, the only subscale in WISC-III with average/above-average scores for the BI-DLD group only was Coding, which taps attentional skills.

The second research question of the current study related to the identification of discrete IQ subtypes across children with DLD, and the investigation of factors possibly underlying their VIQ and PIQ. Unsupervised clustering of VIQ/PIQ profiles converged on three discrete subtypes. Specifically, the largest cluster (n = 133 children) was characterized by average PIQ and affected VIQ ratio, and comprised two thirds of BI-DLD children and almost half of MO-DLD children. The second cluster was almost half in size (n = 57 children) in comparison to the first one; it was characterized by above-average PIQ and average VIQ scores, and it mainly comprised BI-DLD children. The first and second cluster (n = 133 and n = 57, respectively) highlight that BI-DLD children exhibited higher PIQ scores than their MO-DLD peers; the fact that the bilingual children that have participated in the current study were exposed to two languages in fairly equal proportion over their lifespan (mean split 58.4%/41.6% Greek/Albanian; see Table 1) seems to confirm the importance of the balanced use of two languages (Bialystok et al., 2009; Green & Abutalebi, 2013; Gullifer & Titone, 2021; Yow & Li, 2015) in boosting DLD children' PIQ performance over their monolingual peers. Finally, the third cluster was slightly smaller in size than the second one (n = 44 children), and it comprised mainly MO-DLD children whose VIQ and PIQ were both affected (see Table 3). Importantly, the composition of Cluster 3 seems to corroborate previous research with monolingual children with DLD (see Gallinat & Spaulding, 2014 for a meta-analysis) claiming that PIQ is also affected in some children with DLD, and that diagnostic criteria for this disorder should be flexible enough to also include children with below-average PIQ scores (see also DSM–5, American Psychiatric Association, 2013, CATALISE action by Bishop et al., 2017). Notably, maternal education was the only socioeconomic measure to be independently and positively predictive of MO-DLD children's VIQ and PIQ performance, which was unlikely to be explained by other factors, such as paternal education or family income. Previous studies with TD children have similarly found that the associations between maternal education and child cognitive developmental outcomes are stronger than paternal education (Desai & Alva, 1998; Jeong et al., 2017, 2018).

Notably, we did not find any influence of children's language ability on IQ indexes. Previous studies in monolingual children with DLD did make it likely that language could have had a role to play on their PIQ scores (Botting, 2005; Conti-Ramsden et al., 2012). The finding of the current study about the lack of a language ability effect on the children's PIQ scores could be due to the tasks we used to assess language ability. PIQ tests utilize verbal reasoning to a degree (e.g., Durant et al., 2019, Bracken & McCallum, 1998), however, this knowledge pertains to inner speech guiding problem-solving rather than formal language, such as syntax and expressive vocabulary as assessed by the language screening tests of the current study.

The third research question aimed at exploring the interaction between bilingualism and maternal education on the distribution of VIQ/PIQ profiles in children with DLD. According to the results, bilingualism's boosting effect to VIQ and PIQ appeared to only apply to children living in families where the mother had a low level of education, potentially as the result of bilingualism counterbalancing the negative effect that low maternal education would have on the children's VIQ and PIQ performance. This relationship did not hold for children from households with medium maternal education, where MO-DLD children outperformed their bilingual peers in the majority of the VIQ and PIQ tests. The complementary effects of bilingualism and maternal education on IQ performance in DLD suggest that enhanced intellectual functioning does not depend on "all-or-nothing" bilingualism, but rather relies on a complex balance of language experience and the family's maternal education level (Peristeri et al., 2022). Previous research has identified that language difficulties and poor cognitive functioning are often exacerbated by socioeconomic disadvantages in children with DLD (e.g., Lara-Díaz et al., 2021, Locke et al., 2002, McGregor, 2020, also see Sansavini et al., 2021 for a scoping review). Low SES measured through various proxies, including education, income and occupation, has been claimed to offer children fewer linguistic and social experiences within their proximal environment, with negative cascading effects on their language and cognitive development across the lifespan (Place & Hoff, 2016; Tsimpli et al., 2020, see also Hoff, 2006 for a review). The finding that bilingualism had an effect on VIQ and PIQ performance for DLD children coming from households where the mother had a low level of education, suggests that enhanced language experience functioned as a surrogate, maternal education-equivalent for these children.

Notably, according to the mediation analysis of the current study, maternal education predicted DLD bilingual

children's VIQ/PIQ profiles more consistently than other SES indicators. We found null associations between paternal education or family income and bilingual children's IQ outcomes. These results point towards maternal education as the strongest factor over other socioeconomic measures for promoting children's intellectual development, further suggesting the importance of studying mother's and father's education background separately, at least when examining DLD bilingual children's IQ development. We speculate that the dominance of maternal education in IQ development in bilingual children with DLD is once again related to the sociodemographic profiles of the families of the current study; mothers in our sample had a low participation in the labor force, so they tended to spend most of their time at home. The fact that mothers were the primary caretakers throughout the children's lifespan, thus they were assumingly the main providers of child care and the ones stimulating parenting practices, such as learning, play and communication activities, may explain the finding that maternal and not paternal education significantly predicted children's IQ outcomes. Also, the lack of family income effects on children's IQ scores may be explained by the fact that the majority of the parents of the bilingual children in the particular geographical region had low-skilled, low-paid jobs (see Table 1 for the family income measurements), which has probably reduced the effect of the family income variable on the children's IQ performances.

We should note that one limitation that may confound the generalizability of this conclusion is that the MO-DLD-low maternal education and the BI-DLD-low maternal education groups in the current study were not perfectly matched in years of education, since the former group had fewer years of schooling than the latter one (MO-DLD low maternal education: mean = 5.04; BI-DLD low maternal education: mean = 5.76). We should note, though, that none of the mothers falling in the MO-DLD-low and BI-DLD-low groups managed to transition to lower secondary school education, i.e., the maximum score in years of education across both groups was six, which corresponds to the duration of compulsory primary school education in Greece. The fact that the discrepancy in years of education between the two low- maternal education groups was observed for the lowest educational level only, i.e., for children whose mothers failed to either complete compulsory primary school education or/and graduated from elementary school but failed to transition to lower secondary education across both DLD groups, implies that bilingualism effects on IQ were the strongest in children coming from families with the least favorable maternal education profile. A similar pattern was also observed for the paternal education variable, since the fathers of BI-DLD children had significantly more years of schooling than the fathers of MO-DLD children (MO-DLD paternal education: mean = 6.32; BI-DLD paternal education: mean = 7.15); specifically, the MO-DLD group seemed to comprise more children whose fathers failed to complete compulsory primary school education as compared to the BI-DLD group. Whether this difference reflects a mere sample trait or a general sociodemographic characteristic of the BI-DLD population residing in the geographical region of Thessaly, where the current study was conducted, warrants further investigation. We should however not that, according to the statistical analyses, it was maternal and not paternal education that significantly predicted children's IQ outcomes.

The mediation analysis investigating qualitative aspects of DLD children's bilingual status further showed that bilingualism functioned as a possible surrogate for VIQ skills mainly for the children with high oral language input by their parents in each language prior to schooling. Though further research is needed to help us understand this relationship, it seems that fostering dual language exposure at an early age, i.e., before the acquisition of conventional literacy skills at school, may enhance the benefits of bilingualism for the VIQ skills of children with DLD growing up in low maternal education contexts.

Conclusion

To conclude, our study shows that bilingual children with DLD had less affected PIQ performance as compared to their monolingual peers with DLD. This effect was instigated by bilingualism, however, it was explicable in terms of maternal education as a major determinant of children's IQ over and above other socioeconomic characteristics, such as paternal education and family income, since boosting effects to IQ only extended to bilingual children with DLD living in families where the mother had a low level of education. These findings hold substantial implications for our understanding of intellectual functioning in bilingual neurodiverse populations, also highlighting the unique role of maternal education in studying children's cognitive development. Also, our study clearly shows that more research should be carried out in order to better understand the specificities of intellectual functioning in bilingual children with DLD, and to provide these individuals with adequate support and treatment.

Appendix

See Tables 6, 7, 8, 9.

Table 6 Description of the Hellenic WISC-III subtests

VIQ subtests	Description
Information	This test measures general cultural knowledge, long-term memory, and acquired facts. Children are asked questions about different topics like geography, science and historical figures.
Arithmetic	This test measures numerical accuracy, reasoning and mental arithmetic ability.
Similarities	This test measures logical thinking, verbal concept formation and verbal abstract reasoning. Two similar or different objects or concepts are presented, and the child is asked to tell how they are alike or different.
Vocabulary	This test measures the child's verbal fluency and concept formation, word knowledge, and word usage.
Comprehension	This test measures common-sense social knowledge, practical judgment in social situations, and level of social maturation, along with the extent of development of their moral conscience.
Digit Span	This test measures short-term auditory memory and attention. The digits have no logical relationship to each other and are presented in random order by the examiner. The student must then recite the digits correctly by recalling them in the same order. On the second part of this subtest the student must remember the order in which digits are presented but recite them in reverse order.
PIQ subtests	**Description**
Matrix	The child is presented with a series of cards in an incorrect order that must be placed in the correct order to tell a story that makes sense. This task measures an individual's reasoning abilities, and performance is related to the ability to understand precursors and consequences of events.
Coding	The child is given a worksheet where the first line contains a key in which the numbers 1 to 9 are each paired with a different symbol; his/her task is then to use this key to put in the appropriate symbols for a list of numbers between 1 and 9. The test was designed to measure speed of processing, but performance is also affected by other cognitive abilities such as learning, short- term memory and concentration.
Picture concepts	This test measures a child's ability to recognize familiar items and to identify missing parts. The child's task is to separate essential and nonessential parts from the whole and to name or indicate the missing part among several possibilities.
Block design	This test measures an individual's ability to analyze and synthesize an abstract design and reproduce that design from colored plastic blocks. The child must arrange the blocks to match the design formed by the examiner or shown on cards. Spatial visualization and analysis, simultaneous processing, visual-motor coordination, dexterity, and nonverbal concept formation are involved.
Visual puzzles	This test measures the child's ability to analyze and synthesize an abstract design and reproduce that design from colored plastic blocks. Spatial visualization and analysis, simultaneous processing, visual-motor coordination, dexterity, and nonverbal concept formation are involved. The child must fit a number of shapes together to form a recognizable object.
Symbol search	This test requires the child to determine whether a target symbol appears among the symbols shown in a search group. Perception and recognition are the two prime requirements, in addition to speed, accuracy, attention, and concentration. The symbols are geometric forms, rather than familiar letters or numbers.

Table 7 Euclidean distances between the three cluster centroids

Centroid Pair	Distance
Cluster 1 – Cluster 2	8.99
Cluster 1 – Cluster 3	9.01
Cluster 2 – Cluster 3	16.25

Table 8 Groups' maternal education scores on VIQ and PIQ subtest – mean (SD) and minimum-maximum values

		Mo-DLD		BI-DLD	
		Low maternal education (n=94)	Medium maternal education (n=13)	Low maternal education (n=84)	Medium maternal education (n=34)
VIQ	Information	5.70 (2.9) 1–14	8.23 (2.5) 5–14	6.51 (1.6) 2–9	7.09 (1.3) 3–10
	Similarities	5.52 (3.1) 1–13	7.31 (3.5) 1–13	6.27 (1.7) 1–11	6.38 (1.7) 3–11
	Arithmetic	6.47 (3.1) 1–16	9.92 (3.6) 4–16	7.13 (1.7) 1–10	6.18(2) 3–14
	Vocabulary	6–87 (3.4) 1–16	10.23 (3.7) 5–16	7.18 (1.9) 4–10	9.29 (1.8) 7–13
	Comprehension	6.54 (3.3) 1–15	7.85 (3.9) 1–13	7.79 (1.4) 2–10	8.41 (1.6) 4–14
	Digits	5.67 (2.2) 1–13	9.15 (0.9) 7–11	7.24 (2.4) 2–11	7.24 (2.5) 1–11
PIQ	Matrix	8.71 (3.4) 1–17	9.38 (4.1) 4–15	7.86 (2.6) 1–13	9.74 (3.4) 3–14
	Coding	8.41 (3.3) 1–17	9.77 (2.2) 4–12	12.55 (2.1) 9–17	12.12 (1.5) 9–16
	Picture concepts	8.02 (3.0) 1–16	10.85 (3) 7–16	8.80 (2.5) 3–13	8.41 (1.4) 6–12
	Block Design	9.23 (2.7) 3–16	10.92 (3.6) 5–16	10.07 (2.2) 7–14	10.62 (2.7) 6–14
	Visual puzzles	8.14 (3.3) 1–16	11.92 (3.1) 7–16	9.17 (2.8) 2–13	9.18 (3.1) 4–13
	Symbols	8.71 (3.2) 1–15	8.77 (3) 3–13	8.71 (2.1) 5–14	9.65 (3) 4–14

Table 9 Mediation analyses on PIQ and VIQ in the bilingual group with low maternal education scores

Mediation model on VIQ				
	Estimate	SE	z-value	p
VIQ*Home language (b)	−0.089	0.042	−2.112	0.035*
Current language (d)	−0.006	0.045	−0.143	0.886
maternal education (e)	2.524	0.783	3.222	0.001**
Home language*maternal education (a)	5.946	1.240	4.796	<0.001***
Current language* maternal education (c)	2.157	1.359	1.587	0.113
Mediation model on PIQ				
	Estimate	SE	z-value	p
PIQ*Home language (b)	0.061	0.070	0.863	0.388
Current language (d)	0.000	0.077	0.003	0.998
Maternal education (e)	3.354	1.316	2.549	0.011*
Home language*maternal education (a)	5.946	1.445	4.116	<0.001***
Current language* maternal education (c)	2.157	1.675	1.288	0.198

Effect of maternal education mediated by Home language (Greek) history and Current Greek use on PIQ and VIQ

*p<.05, **p<.01, ***p<.001

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Declarations

Competing Interests All authors certify that they have no affiliations with or involvement in any organization or entity with any financial interest or non-financial interest in the subject matter or materials discussed in this manuscript.

Ethical Approval The study was approved by the Institutional review board (IRB) and Ethics Committee of the Aristotle University of Thessaloniki ((IRB protocol number: 39928/20-02-2018). Written informed consent was obtained from the parents or legal guardians of all children involved in the study. The study was performed in accordance with the ethical standards as laid down in the 1964 Declaration of Helsinki.

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