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# Examining the relationship between oral language skills and executive functions: Evidence from Greek-speaking 4–5-year-old children with and without Developmental Language Disorder

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ABSTRACT

*Background:* Children with Developmental Language Disorder (DLD) have been found to demonstrate low performance in Executive Functions (EFs). However, the evidence-based data is so far scarce, especially for 4–5-year-old children. Most of the existing research involves English-speaking populations, while very few studies have been carried out with non-English-speaking populations. Nevertheless, it is documented that possible differences in the language-cognition relations may exist due to the specific characteristics of each language, and studies across different languages could contribute to the above.

*Aims:* The present study aimed to systematically investigate the profile of oral language and EF skills (verbal and nonverbal) and the way these skills are related with each other in 4–5-year-old Greek-speaking children with and without DLD.

*Methods and procedures:* Fifty-three 4–5-year-old children (age range: 51– 57 months) with DLD, and 62 Typically Developing (TD) peers (age range: 51– 57 months) were assessed on a standardized psychometric battery for oral language skills (phonological and morphological awareness, oral language comprehension, vocabulary knowledge, narrative speech and pragmatics) and on a series of verbal (v) and nonverbal (nv) tasks tapping EFs skills (updating-accuracy, inhibition –accuracy and reaction time-, and cognitive flexibility).

*Outcomes and results:* Children with DLD demonstrated statistically significant lower performance across all oral language measures in comparison to their TD peers. Additionally, they performed significantly lower in the updating (nv) task, as well as in cognitive flexibility (v & nv) in comparison to the TD group. Further regression analyses demonstrated that updating (nv), inhibition (nv) and cognitive flexibility (v) predicted oral language comprehension in children with DLD while updating (v & nv), inhibition-reaction time (nv) and cognitive flexibility (v & nv) predicted phonological and morphological awareness, oral language comprehension, narrative speech as well as total language score in TD children.

*Conclusions and implications:* These results provide important information about the profile of oral language and EF skills in children with DLD compared to their TD peers as well as on the

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relationship of these skills in both groups. The findings also suggest that improving EFs skills may be a possible way for improving oral language skills in young children with DLD. Our findings are discussed in terms of their theoretical as well as practical implications regarding the diagnostic and intervention procedures for children with DLD.

## 1. Introduction

Language development is a natural process that starts from the time the baby makes its first sounds and extends to the sixth year when the young child manages to use a language that is quite similar to that of adults (Leonard, 2014). Language acquisition almost always uses common trajectories. By the first year, (TD) children master their first words, build the first phrases and gradually begin to use grammar and long sentences. At the age of 4–5, TD children understand and produce complex sentences to describe events, explain causes and consequences, and predict outcomes. Although sometimes there are differences in the acquisition rate, most of the children acquire their native language by the age they enter primary school (Theakston & Lieven, 2017). However, this natural process may be hard for some children as those with Developmental Language Disorder (DLD) (Bishop, 2006; Leonard, 2014).

Developmental Language Disorder (DLD) - previously known as Specific Language Impairment (SLI) or Language Impairment (LI) - is characterized by difficulties in the acquisition and use of language in the absence of neurological damage, hearing, or cognitive impairment, and concomitant behavioral or emotional disorders (Bishop et al., 2017, pp. 12721). It affects approximately 7.5% of children aged 5;1 – 6;10 months (Norbury et al., 2016; pp. 3, 1257; Tomblin et al., 1997; pp. 3, 1257). DLD is a persistent disorder that can impact different language domains (phonology, morphology, lexicon, syntax and pragmatics) (Bishop, 2006) from preschool to adolescence and adulthood (Brizzolara et al., 2011) and can also result in social, emotional, academic and vocational difficulties (St Clair, Pickles, Durkin, & Conti-Ramsden, 2011).

Several studies have repored that the development of oral language both in children with DLD and TD children is mediated by, and in turn impacts on, other cognitive domains (Law et al., 2017), including Executive Functions (EFs) (Henry, Messer, & Nash, 2012; Lukács, Ladányi, & Fazekas, 2016; Ullman & Pierpont, 2005).

Executive Functions (EFs) refer to a set of cognitive processes that help children control their behavior and attention, delay gratification, resist impulses, manage self-regulation and engage in goal-directed behaviors (Blair & Ursache, 2011). The components of EFs (e.g., updating, prepotent response or resistance to distractor inhibition, cognitive flexibility or shifting) are widely debated in the relevant literature (e.g., Garon, Bryson, & Smith, 2008; Karr et al., 2018; Miyake & Friedman, 2012; Morra, Panesi, Traverso, & Usai, 2018). One of the reasons is that "for some components (e.g., updating) there is a scarcity of tasks suitable for young children and it is possible that a task, especially if complex, taps different abilities during different phases of the development of EF" (Panesi & Morra, 2020, p.74). In our study we adopted the tripartite structure of EFs as this was proposed by Miyake et. al. (2000), which has also been identified in previous studies with preschoolers (Garon et al., 2008) and includes: updating, (the ability to keep track of and continuously monitor and update incoming information), inhibition (the ability to stop prepotent or ongoing responses and resist distractor interference), and cognitive flexibility (the ability to switch between thinking about two different concepts, and to think about multiple concepts simultaneously).

Current research indicates that children with DLD may have lower performance in a wide range of oral language skills and EFs compared to their TD peers (e.g., Leonard, 2014, Henry et al., 2012; Lukács, Ladányi, & Fazekas, 2016), however, the evidence-based data is so far scarce, especially for 4–5-year-old children (e.g., Kapa & Erikson, 2020; Yang & Gray, 2016).

Research also suggests that verbal and nonverbal EFs facilitate language development in TD children and can predict their social, emotional, academic and vocational outcomes (e.g., Blair & Raver, 2015; Clark et al., 2013; Hoff, 2003; McClelland et al., 2013; Miyake, Friedman, Emerson, Witzki, and Howerter (2000). Yet, our understanding of how different aspects of oral language skills relate to specific EFs in the age group of 4–5-year-old children with and without DLD is limited (e.g., Kapa and Erikson, 2020; Marini, Piccolo, Taverna, Berginc, and Ozbič, 2020).

Expanding our knowledge on how certain verbal and non-verbal EFs interact with different oral language skills can be beneficial in the process of assessment and intervention in children with DLD, as "these skills are trainable (Abel et al., 2015; Diamond & Lee, 2011) and predict important life outcomes" (p. 208, Tonér & Gerholm, 2021).

In addition, the current study is, to our knowledge, the first systematic research investigating EFs and oral language skills in 4–5-year-old Greek-speaking children, complementing previous findings from studies mostly involving English-speaking participants. Although human languages have common characteristics, the typological features that are unique to each language should also be taken into account (Leonard, 2014), as it is documented that possible differences in the language-cognition relations may exist due to the specific characteristics of each language (Chrysochoou et al., 2013). Therefore, more cross linguistic research is needed to explore whether similar or different patterns of relationships are identified in different languages. A study in Greek language (which has a rich clitic and morphological system, different from that of English-Leonard, 2014) may offer valuable information for other typologically similar languages, thus, leading to a better understanding of the nature of difficulties that children with DLD are confronted with.

The present study aims to investigate the profile of oral language and EF skills (verbal and non-verbal) and the way these skills are related with each other in 4–5-year-old Greek-speaking children with and without DLD. Our decision to include a plethora of oral language skills as well as both verbal and nonverbal EFs, unlike most previous studies, may shed further light on relationships between different aspects of these abilities in young children with and without DLD.

### 1.1. Executive functions (EFs) in 4–5-year-old children with and without DLD

Research on EFs has mainly focused on 6-year-old or older TD children (e.g., Ralli, Chrysochoou et al., 2021; Weiland, Barata, & Yoshikawa, 2014;) whereas only a few studies have assessed EFs in younger children with DLD (e.g., Kapa & Erikson, 2020, Ralli et al., 2021b, Yang & Gray, 2016). This could be partially explained by a lag in the development of assessment batteries that are designed to tap EFs at a younger age group (e.g., Henry et al., 2012; Morra et al., 2018; Purpura, Schmitt, & Ganley, 2017) and the fact that assessing very young children may lead to floor effects (Friend & Bates, 2014). A limited number of studies has examined EFs (either one of them or more than one) in 4–5-year-old children with DLD (e.g., Farrant, Mayberry, & Fletcher, 2012; Kapa, Plante, & Doubleday, 2017; Kapa & Erikson, 2020; Marini et al., 2020; Roello, Ferretti, Colonnello, & Levi, 2015; Yang & Gray, 2016) and to our knowledge only one study (Yang & Gray, 2016) has investigated the three core EFs according to the model proposed by Miyake et al. (2000).

More specifically, Farrant et al. (2012) reported that children with DLD (48–74 months), had significant difficulties on cognitive flexibility (nv) compared to their TD peers who were matched on gender, nonverbal ability, and age (46–76 months). Marini et al. (2020) also found that Italian-speaking children with DLD ($M_{age}$=5.19) were outperformed on prepotent response inhibition (v) tasks by their TD peers ($M_{age}$=5.43). Similar outcomes were reported by Kapa and Erikson (2020) and Roello et al. (2015); Four- to six-year-old children with DLD had significant difficulties on prepotent response inhibition (v) and cognitive flexibility (nv) relative to TD participants.

However, only two studies (Kapa et al., 2017; Yang & Gray, 2016) have systematically investigated verbal and nonverbal EFs in 4–6-year-old English-speaking children with and without DLD. Kapa et al. (2017) investigating prepotent response inhibition and cognitive flexibility found that children with DLD had worse performance on inhibition (v) and cognitive flexibility (nv) than their matched-on gender and age TD peers. On the other hand they found that both groups of children demonstrated similar performance on inhibition (nv) and cognitive flexibility (v). In parallel, Yang and Gray (2016) investigated updating, resistance to distractor inhibition and cognitive flexibility in 4- and 5-year-old English-speaking children with and without DLD, matched on age, reporting significant differences on verbal and nonverbal updating as well as on verbal cognitive flexibility in favor of TD children while no differences were found on inhibition (both verbal and nonverbal) and cognitive flexibility (nv) between the two groups of children.

Therefore, it is well documented that 4–6-year-old children with DLD have significant difficulties on prepotent response inhibition (v) (Kapa & Erikson, 2020; Marini et al., 2020; Roello et al., 2015) and cognitive flexibility (nv) (Farrant et al., 2014; Kapa & Erikson, 2020; Roello et al., 2015). However, the findings for updating (v & nv), resistance to distractor interference inhibition (v & nv) and cognitive flexibility (v) are still scarce and inconclusive. Differences in the methodological procedures of the above studies in terms of the age (wide age range which results in mixed age groups) and the demographic characteristics of the participants (e.g., SES, parental education), the types of tasks (verbal or nonverbal), and the tools for data collection (other tap working memory or updating, inhibition as a prepotent or resistance to distractor interference) may influence children's performance on tasks measuring oral language and EFs thus rendering the comparison of the results difficult for safe conclusions (Kapa et al., 2017).

In summary, there is a need for further systematic exploration of a series of oral language skills as well as of both verbal and nonverbal EF skills in specific age groups (one year age range) of young children with and without DLD that have similar demographic characteristics (e.g., SES, parental education) as the latter may influence children'sperformance on tasks measuring language and EFs, (Kapa et al., 2017).

### 1.2. The relationship between Executive functions (EFs) and oral language skills in 4–5-year-old children with and without DLD

There is research evidence from cross-sectional and longitudinal studies with TD children that EFs facilitate specific oral language skills (e.g., vocabulary in 4-year-old English-speaking children: Weiland et al., 2014; grammar in 3–5 years old German speaking children: Slot & von Suchodoletz, 2018).

However, only a limited number of studies have investigated the relationship between the three core EFs (according to Miyake et al., 2000: updating, inhibition and cognitive flexibility) -individually or systematically- and different oral language skills in both 4–6- year-old TD children and children with DLD. More specifically, regarding TD children, a few studies have reported significant associations among verbal inhibition and the following language skills: pragmatics (in French-speaking children: Blain-Briere et al., 2014), receptive and expressive vocabulary (in English-speaking children: Kapa & Erikson, 2020), oral language comprehension (in English-speaking children: Fuhs et al., 2014; in Croatianspeaking children: Šimleša, Cepanec, & Ljubešić, 2017) and morphosyntactic accuracy (in Swedish-speaking children: Tonér & Gerholm, 2021).

On the contrary, no significant correlations have been found between cognitive flexibility and pragmatics (Blain-Briere et al., 2014) or receptive and expressive vocabulary (Kapa & Erikson, 2020).

Regarding 4–6-year-old children with DLD, very few studies have investigated the relationship between EFs and oral language skills. Marini et al. (2020) demonstrated significant correlations among inhibition (v) and the following oral language skills: phonological discrimination, grammatical comprehension, and narration in Italian-speaking children. Kapa and Erikson (2020) showed significant associations among inhibition (v) and receptive and expressive vocabulary as well as between cognitive flexibility (nv) and expressive vocabulary in 4–6-year-old English-speaking children with DLD.

In sum, the results of the above studies, although limited and newfound, suggest possible different relationships between aspects of language and inhibition (v) in 4–6-year-old TD children and children with DLD. However, further research is needed to explore how oral language skills relate with updating and shifting in this age group, as the current findings are either scarce or nonexistent.

### 1.3. The present study

The aims of the present study were (a) to compare the performance of 4–5-year-old Greek - speaking children with and without DLD on a series of oral language skills (phonological and morphological awareness, language comprehension, vocabulary knowledge, narrative speech, and pragmatics) as well as on the three core EFs (updating, inhibition and cognitive flexibility)-both verbal and nonverbal-, and (b) to investigate possible interrelations between the aforementioned skills. More specifically, the research questions were the following:

1. Do Greek-speaking 4–5-year-old children with DLD perform worse on a series of oral language (phonological and morphological awareness, oral comprehension, vocabulary knowledge, narrative speech, and pragmatics) and EF skills (updating, inhibition-resistance to distractor-, and cognitive flexibility), verbal and non-verbal, in comparison to their TD peers?
2. To what extent are the EFs related with the oral language skills in Greekspeaking 4–5-year-old children with and without DLD?

#### 1.3.1. We stated the following hypotheses

We expected children with DLD to be outperformed by their TD peers in both verbal and nonverbal EF tasks as well as across all oral language measures (Leonard, 2014; Marini, Piccolo, Taverna, Berginc, & Ozbič, 2020; Ralli, Kazali, & Karatza, 2021a). Regarding the second research question, we opted for a general hypothesis, given the scarce findings in the literature as well as the paucity of evidence with 4–5-year-old children with and without DLD. We expected, based on previous research, that inhibition (v) would predict oral language comprehension, in TD children (Šimleša et al., 2017). For the children with DLD we assumed that inhibition (v) would be associated with phonological awareness, narrative speech as well as with receptive and expressive vocabulary (Kapa & Erikson, 2020; Marini et al., 2020).

## 2. Methods

### 2.1. Participants

A total of 115 children aged 4–5-year-old participated in the study. In Greece, 4-5-year-old children attend preschool settings and they start primary education at the age of 5 when they enter kindergarten. Fifty-three children with DLD (32% girls, 68% boys) and 63 TD peers (58% girls, 42% boys) (mean age for each group 53.36 and 53.63 respectively) were recruited from the area of South-east of Attica in Greece. All participants had average non verbal intelligence with a standard score of 85 or above in the Raven's Educational CPM/CVS (Raven & Court, 1998) which is standardized for use with Greek children by Sideridis, Antoniou, Mouzaki, and Simos (2015). Children with a diagnosed hearing impairment, neurological disorder, ADD/ADHD, or autism spectrum disorder were excluded from the sample. We recruited children with DLD based on an existing relevant diagnosis from a speech and language pathologist (working at the local Community Centre for Mental Health of Children and Adolescents according to DSM-V -American Psychiatric Association, 2013), which was further confirmed with additional assessments. Specifically, following Tomblin (1996), children with DLD had to perform approximately 1.25 SDs or more below the mean on two standardized language measures (receptive vocabulary and picture naming-included in the standardized Greek assessment Logometro, Mouzaki, Ralli, Antoniou, Diamanti, & Papaioannou, 2017). All children from the TD group performed in the normal range on both measures (Table 1).

There were no differences between groups in terms of age [$t(113) = 0.886$, $p = .388$], family socio-economic status [$\chi^2$ (2)= 5.571, $p = .062$] and maternal education [$\chi^2$ (4)= 8.663, $p = .070$].

### 2.2. Material

#### 2.2.1. Executive functions measures

Executive functions were assessed with a series of 6 online tasks particularly designed for the purposes of the present study which were based on Yang's study (2015) (See Yang & Gray, 2016 for the procedure of administration, descriptions, and illustrations of the tasks).

EF tasks were translated in Greek and then back into English to check for accuracy. Firstly, the tasks were pilot tested with twenty 4–5-year-old children (9 TD children and 11 children with DLD). Substantial modifications from the original experimental test of Yang and Gray (2016) were made in wording in order for the instructions to a) be relevant to the Greek context, b) be easily understood by

**Table 1**
Descriptive statistics and Independent Sample T test for both groups' inclusion criteria.

| | TD (n = 62) | DLD (n = 53) | Independent Samples T Test | | | |
|---|---|---|---|---|---|---|
| | Mean (SD.) | Mean (SD.) | t | df | p value | Cohen's d |
| Age in months | 53.63 (2.2) | 53.36 (2.4) | .663 | 113 | .425 | 0.11 |
| Raven | 109.75 (11.6) | 107.64 (12.3) | .948 | 113 | .345 | 0.25 |
| Receptive vocabulary | 20.66 (2.1) | 10.57 (1.4) | 9.74 | 91.44 | < 0.001 | 2.04 |
| Picture naming | 16.64 (2.6) | 7.34 (3.0) | 8.15 | 103.88 | < 0.001 | 1.60 |

young children and also c) reassure that a minimum level of language ability was required in both verbal and non-verbal tasks, as it is shown in the presentation of the questions used for each task in Table 2.

For the same purpose, there was also a training block for each task that children had to pass successfully in order to further participate in the EF assessment. Before each testing phase, children were reminded of the rules for each one of the task and were asked to demonstrate knowledge of the rules by correctly answering specific questions (see Table 2). To avoid possible ceiling effects in the performance of TD children in the cognitive flexibility tasks, we also added one extra block of testing to the one designed by Yang (2015). Instead of using only two phases (the pre-switch phase, where each child had to short the cards according to one dimension-shape/or color- and the post-switch phase, where each child was asked to sort the cards according to the other dimension) we added a third phase, in which each child had to sort the cards according to the first dimension, making the task more difficult.

### 2.3. Oral language measures

Oral language skills were assessed using, the standardized psychometric digital tool Logometro, for Greek speaking children aged 4–7 years (Mouzaki et. al. 2017). Logometro taps on phonological and morphological awareness, oral language comprehension, vocabulary knowledge, narrative speech, and pragmatics, through 24 tasks (see Table 3 for details).

The test provides a separate raw score (the sum of the correct answers) for each one of the tasks, a composite score for each linguistic domain (phonological awareness, morphological awareness, oral language comprehension, vocabulary knowledge, narrative speech and pragmatics) and a total composite language score reflecting each child's language ability. In our statistical analyses we used the separate score for each one of the tasks, with the exception of phonological and morphological awareness where we decided to use the composite scores in order to avoid floor effects in children's performance.

### 2.4. Demographics questionnaire

Children's demographic information (e.g., date of birth, gender, parental education, socioeconomic status - SES) was obtained from parents/caregivers by asking them to complete a demographics questionnaire. For parental education, the participants had to check their educational level by choosing one of the following (elementary school, secondary education -high school, post-secondary education, BSc and Master-PhD) (Ralli, Chrysochoou et al., 2021; Vivas et al., 2017).

SES was calculated by summing up three ratings regarding parental education level (from 1 elementary school to 5 MSc or PHD), type of occupation (blue or white collar) and position in occupation (from 1-unskilled worker to 5- executive member of the private or public sector), in the same fashion as in other related studies (Ralli, Chrysochoou et al., 2021; Vivas et al., 2017).

### 2.5. Procedure

All tasks were presented on a computer equipped with DMDX program to run the EF tasks (Forster & Forster, 2003). During the administration of the tasks, all necessary procedures were followed, according to their creators (Mouzaki et al., 2017; Yang, 2015).

The participants were examined by the researcher in a quiet room. The tests were administered individually in a random order; the

**Table 2**
Brief Description of Executive Function Tasks and Reported Cronbach's a.

| Executive Functions Tasks | Type | Question | Cronbach's a |
|---|---|---|---|
| **Updating** Verbal | **N-back type task** (seeYang & Gray, 2016). The child has to compare each incoming stimulus-picture on a computer screen with the one presented previously. Images of 8 simple items (horse, apple, flower, duck, chair, shoe, hat, car) | "Is this the same or different? Or "Is it the same? Yes or no" | .83 |
| Non-verbal | **N-back type task** (seeYang & Gray, 2016). The child has to compare images of a butterfly at 8 different location in the computer screen. | "Is butterfly on the same or different location? or "Is it in the same location? Yes or no" | .84 |
| **Inhibition** Verbal | **Flanker type task** Rows of 5 dogs, 5 cats, (congruent condition) 4 dogs with a cat in the middle and 4 cats with a dog in the middle (incongruent condition); the child must identify the animal in the middle by pronouncing the name of the animal (seeYang & Gray, 2016). | "Who is in the middle?" | .95 |
| Non-verbal | **Flanker type task.** Rows of 5 fishes, looking either at the same direction (congruent condition), or the middle looking at the opposite direction of the other 4 (incongruent condition); the child must push the right or left shift button on the keyboard according to the direction that the middle fish is looking at (seeYang & Gray, 2016). | Where does the fish in the middle look? | .85 |
| **Cognitive flexibility** Verbal | **Sorting card task** based onYang (2015) adaptation of the Dimensional Change Card Sorting task (Diamond, Carlson, & Beck, 2005). Images of scissors on a red background and glasses on a blue background; the child must sort out the cards according to the presented dimension (either by object or color) by pushing the right or left shift button on the keyboard. | "Where does this card goes?" | .88 |
| Non-verbal | **Sorting card task** based onYang (2015) adaptation of the Dimensional Change Card Sorting task (Diamond et al., 2005). Images of a polygon on a bag and another polygon on another bag; same procedure as in verbal task. | "Where does this card goes?" | .86 |

**Table 3**
Brief Description of Oral Language Tasks and Reported Cronbach's a.

| Language skills | Task | Cronbach's a |
|---|---|---|
| **Phonological awareness** | **Identification of similar syllable and phoneme**: each child had to choose which of the three images, presented on the screen, begun with the same syllable or phoneme as the target image.<br>**Syllable and phoneme-synthesis**: each child had to compose words from specific syllables or phonemes.<br>**Syllabic and phonemic segmentation**: each child had to listen to a word and then was asked to analyze it in syllables as well as in phonemes accordingly.<br>**Syllable-deletion, and phoneme-deletion**: each child was asked to listen carefully to a word and then to repeat it by deleting a syllable or a phoneme accordingly. | Composite score:.75 |
| **Morphological awareness** | **Production of derivational suffices**: each child had to choose which one of the two talking penguins produced the sentence with the correct words.<br>**Comprehension and production of inflectional suffices of nouns and verbs**: each child had to choose or to produce a correct sentence following specific instructions. | Composite score:.78 |
| **Oral language comprehension** | **Listening comprehension of instructions**:after listening to a sentence, each child was asked to point to the picture out of a selection of four that corresponds to that sentence. | .73 |
| | **Listening comprehension of a story**: after listening to a story each child had to answer to 6 questions, e.g. 'who took the card from the bookshelf?' | .71 |
| **Vocabulary knowledge** | **Receptive vocabulary**: each child was asked to choose the picture, out of a selection of four, that represents the word they were asked to point to. | .88 |
| | **Naming**: each child was asked to look at a picture and then to name it. | .73 |
| | **Word definition**: each child was asked to give a brief definition of a series of words. | .93 |
| **Narrative speech** | **Free narration**: each child is asked to describe six simple pictures that constitute a story of a birthday party. | .85 |
| | **Retelling**: after listening to a story of two children playing in a park, each child was asked to repeat it giving as many details as they could possibly remember. References in the agents, the event, the problem and the potential solution get the appropriate scores | .73 |
| **Pragmatics** | Each child was asked to respond in the most appropriate way to the examiner's questions, regarding the *interpretation of the communicative situation* presented in the picture, the *intention/ability to communicate* the *response to communication,* the *interactional skills that are related to the contextual variation.* | .81 |
| **Total language score** | A total score reflecting the child's language ability | .81 |

children were assessed initially on the oral language tasks and subsequently on the EF tasks in two 45 minute-sessions administered in 2 separate testing days within a month. The research received ethical clearance from the Institute of Educational Policy, Department of Ministry of Education (Φ15/ 226369/2655/Δ1) and all parents/ caretakers gave their written consent for their child in order to participate in the research.

## 3. Results

### *3.1. Do Greek-speaking 4–5-year-old children with DLD perform worse on a series of oral language (phonological and morphological awareness, oral comprehension, vocabulary knowledge, narrative speech, and pragmatics) and EF skills (updating, inhibition-resistance to distractor-, and cognitive flexibility), verbal and non-verbal, in comparison to their TD peers?*

We proceeded with t-tests for independent samples to compare the two groups (TD vs. DLD) on EFs and oral language skills as the assumption of normal distribution of the variables was not violated. Children's performance in both oral language and EF skills is presented in Tables 4 and 5 respectively. As it can be seen, children with DLD had significantly lower performance across all oral language tasks as well as in the total language score compared to their TD peers.

Regarding EFs, the results revealed that children with DLD had more difficulties in both verbal and non-verbal updating and cognitive flexibility tasks than their TD peers. The differences were found to be significant for the updating (nv) and cognitive flexibility (v & nv). On the other hand, the performance of both groups of children did not differ on the inhibition tasks (both verbal and

**Table 4**
Group Comparisons (Mean, Standard Deviation and T-tests) of the oral language skills.

| | TD (N = 62) | DLD (N = 53) | Independent Samples T Test | | | |
|---|---|---|---|---|---|---|
| Oral language skills | Mean (S.D.) | Mean (S.D.) | t | df | p value | Cohen's d |
| Phonological Awareness | 48.47 (23.9) | 23.02 (21.3) | 3.5 | 113 | .001 | 1.14 |
| Morphological Awareness | 77.11 (15.8) | 45.43 (25.2) | 2.3 | 113 | .022 | 1.72 |
| Listening Comprehension- instructions | 12.10 (2.1) | 8.49 (2.6) | 8.3 | 113 | .001 | 1.64 |
| Listening Comprehension- Story | 4.00 (0.9) | 2.51 (1.1) | 8.0 | 113 | .001 | 1.59 |
| Receptive Vocabulary | 20.66 (3.1) | 13.57 (4.4) | 9.7 | 91.4 | .001 | 2.04 |
| Naming | 13.64 (2.6) | 9.34 (3.0) | 8.1 | 103.9 | .001 | 1.60 |
| Word Definition | 12.68 (2.9) | 7.22 (3.6) | 8.9 | 100.0 | .001 | 1.78 |
| Free Narration | 2.16 (1.1) | 0.91 (0.7) | 7.2 | 105.7 | .001 | 1.40 |
| Retelling | 3.48 (1.6) | 1.60 (1.1) | 7.3 | 105.6 | .001 | 1.44 |
| Pragmatics | 76.13 (19.9) | 43.49 (27.5) | 7.3 | 113 | .001 | 1.49 |
| Total Language Score | 69.25 (16.9) | 25.62 (15.8) | 14.2 | 113 | .001 | 2.70 |

**Table 5**
Group Comparisons (Mean, Standard Deviation and T tests) of executive function skills.

| | TD (N = 62) | DLD (N = 53) | Independent Samples T Test | | | |
|---|---|---|---|---|---|---|
| Executive Functions | Mean (S.D.) | Mean (S.D.) | t | df | p value | Cohen's d |
| *Updating* | | | | | | |
| Verbal | 83.20 (16.0) | 79.34 (14.7) | 1.3 | 113 | 0.185 | 0.25 |
| Nonverbal | 66.80 (18.7) | 53.61 (14.4) | 4.3 | 111.9 | < 0.001 | 0.79 |
| *Inhibition* | | | | | | |
| Verbal: Accuracy[a] | -3.13 (9.0) | -4.36 (7.4) | .8 | 113 | .419 | 0.15 |
| Reaction time[a] | 164.94 (216.7) | 147.44 (177.1) | .5 | 112.8 | .635 | 0.09 |
| Nonverbal: Accuracy[a] | -3.48 (11.2) | -3.17 (18.8) | -0.1 | 113 | .913 | 0.02 |
| Reaction time[a] | 427.03 (591.9) | 495.50 (666.3) | -0.6 | 113 | .561 | 0.11 |
| *Cognitive Flexibility* | | | | | | |
| Verbal | 63.68 (31.64) | 47.63 (25.74) | 2.9 | 113.00 | .003 | 0.55 |
| Nonverbal | 49.46 (30.26) | 42.84 (26.53) | 1.2 | 113.00 | .218 | 0.23 |
| Total Cognitve Flexibility | 56.57 (26.18) | 45.24 (21.39) | 2.6 | 112.8 | .012 | 0.47 |

Note: [a] Variables with lower scores denote better development; DLD= Developmental Language Disorder; TD= typically developing

non-verbal) (Table 5).

### 3.2. To what extent the EFs are related with the oral language skills in Greek speaking 4–5-year-old children with and without DLD?

To investigate possible relationships between EFs and oral language skills, Pearson's correlation coefficients were calculated, as all linearity tests provided no evidence that there was any deviation from linearity (all $p > .05$). The results revealed weak to moderate correlations between EFs and oral language skills for both groups (Table 6 & 7). In both groups a few common correlation patterns were identified. Therefore inhibition-reaction time (nv) and updating (nv) were significantly correlated with listening comprehension-story, while cognitive flexibility (nv) was significantly correlated with retelling. On the other hand, several different patterns of correlations were identified for each group of children. More specifically, regarding the children with DLD, updating (nv) showed a significant positive correlation with receptive vocabulary, while cognitive flexibility (v) was negatively correlated with free narration and positively with listening comprehension-story. Finally, cognitive flexibility (nv) was positively associated with listening comprehension-instructions.

Regarding TD children, it was found that inhibition-accuracy (v) was negatively correlated with retelling; inhibition-accuracy (nv) was positively correlated with morphological awareness, suggesting that children who needed more time to accurately complete the inhibition task had better performance in the morphological awareness task. Similarly, inhibition-reaction time (v)was positively correlated with phonological awareness whereas inhibition-reaction time (nv) was negatively correlated with pragmatics. Updating (v & nv) showed a significant positive correlation with the listening comprehension (instructions and story) measures. Finally, cognitive flexibility (v) was positively correlated with phonological and morphological awareness and retelling, whereas cognitive flexibility (nv) was correlated with morphological awareness, listening comprehension-story and free narration (Table 7).

To further explore the significant correlations identified between EF skills and oral language skills in each group of children linear regression analyses using the enter method were performed for each group separately, since different patterns of relationships have also been suggested by previous research for each separate group (Blom & Boerma, 2019; Masten & Cicchetti, 2010). All necessary assumptions of regression were met. In the enter process the criterion variable (i.e., each language skill that was correlated with more than one EF skills) as well as all predictor variables (i.e., the EFs that were significantly correlated with each criterion variable) were introduced simultaneously to the analyses assuming that all predictors will be given equal importance in our model.

The results of each enter process for both groups of children are presented in Tables 8 and 9. For children with DLD, the model indicated that inhibition-reaction time (nv), updating (nv) and cognitive flexibility (v) explained 21% of the variance in children's performance on the listening comprehension-story task, with updating (nv) and cognitive flexibility (v) to be statistically significant predictors.

Regarding TD group, the model indicated that cognitive flexibility (v) and inhibition-reaction time (v) explained 20% of the variance in phonological awareness scores with cognitive flexibility (v) to be the only significant predictor. Furthermore, it was found that cognitive flexibility (v & nv) and inhibition-accuracy (nv) explained 18% of the variability in children's performance in the

**Table 6**
Correlation Coefficients Between EFs and Oral Language Skills for Children with DLD (N = 53).

| | Receptive vocabulary | Listening comprehension- instructions | Listening comprehension- story | Free narration | Retelling |
|---|---|---|---|---|---|
| [a]Inhibition: R.T. (nv) | .03 | -0.16 | -0.29* | .02 | .05 |
| Updating (nv) | .30* | .24 | .28* | .02 | .13 |
| Cognitive flexibility: (v) | .18 | .09 | .34* | -0.29* | -0.19 |
| Cognitive flexibility: (nv) | .01 | .29* | .03 | -0.02 | .28* |

Notes: * Correlation is significant at the 0.05 level (2-tailed), [a] Variable in which lower scores denote better development; V= verbal; NV= nonverbal; R.T.= reaction time, CF= cognitive flexibility.

**Table 7**
Correlations Coefficients Between EFs and Language Skills for Typically Developing Children (N = 62).

| | Phonological awareness | Morphological awareness | Listening comprehension-instructions | Listening comprehension -Story | Free narration | Retelling | Pragmatics | Total language |
|---|---|---|---|---|---|---|---|---|
| [a]Inhibition-Accuracy (v) | .01 | -0.10 | .22 | -0.10 | -0.20 | -0.34** | -0.13 | .08 |
| [a]Inhibition-R. T. (v) | .28* | .19 | .20 | -0.04 | .07 | .04 | .12 | .05 |
| [a]Inhibition-Accuracy (nv) | -0.01 | .31* | .08 | .11 | .16 | .25 | .21 | -0.01 |
| [a]Inhibition-R. T. (nv) | -0.05 | -0.02 | -0.02 | -0.26* | -0.22 | -0.23 | -0.27* | -0.29* |
| Updating (v) | .11 | .09 | .37** | .25* | -0.04 | .16 | -0.02 | .15 |
| Updating (nv) | .15 | .07 | .28* | .27* | -0.08 | .16 | -0.07 | .35** |
| Cognitive flexibility (v) | .41** | .32* | .07 | .22 | .15 | .32* | .05 | .39** |
| Cognitive flexibility (nv) | .17 | .27* | -0.08 | .35** | .34** | .37** | .23 | .32* |
| Cognitive flexibility: Total | .35** | .35** | -0.01 | .33** | .29* | .41** | .16 | .42** |

Notes: * Correlation is significant at the 0.05 level (2-tailed), ** Correlation is significant at the 0.01 level (2-tailed). [a] Variable in which lower scores denote better development; V= verbal; NV= nonverbal; R.T.= reaction time; CF= cognitive flexibility.

**Table 8**
Linear Regressions Predicting Performance on Language Skills in Children with DLD (N = 53).

| Criterion variable | Predictors | Model | | |
|---|---|---|---|---|
| | | *B* | *SE B* | *β* |
| Listening comprehension-story | Inhibition-RT (nv) | .00 | .00 | -0.19 |
| | Updating (nv) | .02 | .01 | .24* |
| | Cognitive flexibility (v) | .01 | .01 | .31* |
| | $R^2$ | .21 | | |

Notes: * $p < .05$, ** $p < .01$, *** $p < .001$; V= verbal; NV= non-verbal; RT= Reaction Time

**Table 9**
Linear Regressions Predicting Performance on Language Skills in TD Children (N = 62).

| Criterion variable | Predictors | Model | | |
|---|---|---|---|---|
| | | B | SE B | β |
| Phonological awareness | Cognitive flexibility (v) | .31 | .09 | .41** |
| | Inhibition-reaction time (v) | -0.01 | .01 | -0.11 |
| | $R^2$ | .19 | | |
| Morphological awareness | Cognitive flexibility (v) | .12 | .07 | .25* |
| | Inhibition-accuracy (nv) | -0.01 | .00 | -0.24* |
| | Cognitive flexibility (nv) | .05 | .07 | .09 |
| | $R^2$ | .18 | | |
| Listening comprehension- instructions | Updating (v) | .04 | .02 | .31* |
| | Updating (nv) | .02 | .02 | .14 |
| | $R^2$ | .15 | | |
| Retelling | Cognitive flexibility (nv) | .02 | .01 | .36* |
| | Inhibition-Accuracy (nv) | .02 | .02 | .17 |
| | Cognitive flexibility (v) | .01 | .01 | .18 |
| | $R^2$ | .25 | | |
| Total language Score | Cognitive flexibility (v) | .13 | .07 | .24 |
| | Inhibition-RT (nv) | -0.01 | .00 | -0.22 |
| | Updating (nv) | .28 | .11 | .31** |
| | Cognitive flexibility (nv) | .08 | .07 | .15 |
| | $R^2$ | .31 | | |

Notes: * $p < .05$, ** $p < .01$; V.= verbal; NV= non-verbal; RT= Reaction Time.

morphological awareness tasks with cognitive flexibility (v) and inhibition-accuracy (nv) to be the only significant predictors. It was also demonstrated that updating (v & nv) explained 15% of the variability in children's performance in the listening comprehension-instructions with updating (v) being the only significant predictor.

Additionally, the results showed that cognitive flexibility (v & nv) and inhibition-accuracy (v) explained 25% of the variability in children's performance in the retelling task, with cognitive flexibility (nv) being the only significant predictor. Finally, the analysis demonstrated that cognitive flexibility (v & nv), updating (nv) and inhibition-reaction time (nv) explained 31% of the variance in children's total language score where updating (nv) was the only significant predictor (Table 9).

## 4. Discussion

The aim of the present study was (a) to compare the performance of 4–5-year-old Greek-speaking children with and without DLD in a series of oral language skills (phonological and morphological awareness, language comprehension, vocabulary knowledge, narrative speech, and pragmatics) as well as in the three core EFs (updating, inhibition and cognitive flexibility)-both verbal and nonverbal-, and (b) to investigate possible interrelations between these skills. To our knowledge, this is the first study that has attempted the assessment of the above skills and the investigation of their relationship in 4–5-year-old children with and without DLD.

Our first research question investigated whether 4–5-year-old Greek-speaking children with DLD perform worse in a series of oral language and EFs skills compared to their TD peers. As it was predicted, children with DLD had poorer performance across all oral language measures (phonological and morphological awareness, oral language comprehension, vocabulary, narrative speech and pragmatics), compared to TD children, (Leonard, 2014). This finding suggests that a thorough assessment of both receptive and expressive language skills in children with DLD is necessary in order to map individual relative strengths and weaknesses and carry out effective intervention programs (Marini et al., 2020).

Regarding EFs, our hypothesis that children with DLD would be outperformed by their TD peers in both verbal and nonverbal EFs was confirmed in most cases. More specifically, we found that children with DLD had deficits in both verbal and nonverbal updating; these findings constitute novel evidence to our limited knowledge about updating in children with DLD (Ralli, Chrysochoou et al., 2021). Our results also demonstrated that 4–5-year-old children with DLD had difficulties in cognitive flexibility, both verbal and nonverbal, compared to their aged-matched TD peers. This finding could support the idea that cognitive flexibility possibly emerges around the age of 4. The function of cognitive flexibility has been found to be important in the process of learning new words (Miyake et al., 2000; pp. 1, 1272; Šimleša et al., 2017; pp. 1, 1272) and any possible deficits in this domain may also account for the vocabulary difficulties that children with DLD are constrained with. To our knowledge, this is the first time that a study demonstrates that this age-group of children with DLD have domain general deficits (verbal and non-verbal) in cognitive flexibility; previous studies have demonstrated inconsistent results [some of them found deficits in nonverbal cognitive flexibility only (e.g., Kapa et al., 2017, Roello et al., 2015) others in verbal cognitive flexibility only (Yang & Gray, 2016)]. Furthermore, Reichenbach, Bastian, Rohrbach, Gross, and Sarrar (2016) reported no group differences on nonverbal cognitive flexibility using a similar to our study task. Differences in the methodological procedure regarding the mean age of the participants in Reichenbach's and our study (63 months in their study versus 53 months in ours), and the fact that previous studies also included family SES in their statistical analyses may account for these conflicting findings. Our results also indicate that 4–5-year-old children with DLD have difficulties in continuously monitoring incoming information (updating) and in finding new approaches to solve problems (cognitive flexibility). As both these skills are involved in language learning (e.g., vocabulary, narration) (Diamond, 2013; Fuhs & Day, 2011; Miyake et al., 2000; White, Alexander, & Greenfield, 2017), deficits in updating and cognitive flexibility may be a clinical characteristic of this group of children. This outcome adds evidence to causal theories [e.g., Morton and Frith's "causal model of developmental psychopathology", (1995), Dynamic Systems Theory (Thelen & Smith, 1998), Pennington's "Multiple Deficit Model" (2006)] which support the hypothesis that multiple possible risk factors including cognitive skills, account for a neurodevelopmental disorder, such as DLD. Future research could further explore the present findings, as this could have important implications for diagnosis and intervention in children with DLD.

Another interesting finding of our research was that no significant differences were found between groups in their performance on the inhibition tasks implying that both groups have similar ability to ignore irrelevant information, at least in the age of 4–5-year-old. Yang and Gray (2016) reached similar results using the same task measuring resistance to distractor interference. Further research is needed to possibly replicate the above findings not only cross-sectionally but also longitudinally and to investigate whether children with DLD have deficits in other aspects of inhibition, such as prepotent response inhibition (Kapa et al., 2017; pp. 1, 1272; Marini et al., 2020; pp. 1, 1272; Roello et al., 2015; pp. 1, 1272).

In sum, 4–5-year-old Greek - speaking children with DLD exhibit (a) deficits across all oral language skills measured in the present study and (b) domain general deficits (verbal and non-verbal) in updating and cognitive flexibility in comparison to their TD peers. Future studies using a longitudinal research design could further investigate whether deficits in updating and cognitive flexibility that were demonstrated in children with DLD in our study reflect a developmental delay in EFs or constitute a different pattern of EFs' development in each group of children (i.e., a permanent deficit in EFs in the DLD group). Furthermore, not only computerized direct assessment but also additional forms of assessment (e.g., parent/teacher reports, dynamic assessment) in which data is collected with reference to how a child performs in different environments, could be used in future research to obtain more information about the complex nature of oral language and executive functioning.

Our second research question examined possible relationships between EFs and oral language skills in each group of children. Regarding TD children, our hypothesis that inhibition (v) would predict oral language comprehension was also confirmed. More specifically, our results showed that inhibition (v) together with cognitive flexibility (v & nv) predicted retelling skills, thus adding new evidence to the so far limited literature (Friend & Bates, 2014). This finding indicates that the ability to suppress semantic competitors

is important for understanding a story as well as for monitoring the selection of appropriate words and sequencing of episodes within a narrative discourse (retelling). We also found that updating (v & nv) predicted listening comprehension (instructions) suggesting that the ability to continuously replace outdated information with new relevant data facilitates children in the process of listening comprehension. In addition, verbal and nonverbal cognitive flexibility were the most significant predictors of phonological and morphological awareness in this group of children. It seems that the ability to flexibly direct attention to another dimension may be a useful resource that could facilitate phonological (such as identification, synthesis, and deletion of phonemes or syllables) and morphological skills (such as comprehension and production of derivational and inflectional suffices) in this group of children.

Regarding possible relationships between EFs and oral language skills in children with DLD our hypothesis that inhibition (v) would be associated with phonological awareness, narrative speech, receptive and expressive vocabulary was not fully confirmed. We found that nonverbal inhibition and updating as well as verbal cognitive flexibility predicted listening comprehension (story) which adds to previous findings that EFs promote oral language comprehension (Fuhs et al., 2014). Our results are also consistent with Miyake's theory (Miyake et al., 2000) that the ability to suppress irrelevant semantic information, to update incoming data and to swift between mental sets support children in the process of story comprehension.

No other EFs predicted oral language skills of children with DLD – contrary to our hypotheses (Kapa & Erikson, 2020); The above could be possibly explained by the differences in the age range of the participants (51–57 months in our study and 50–68 months in Kapa & Erikson's study) as well as by the aspects of inhibition measured (resistance to distractor interference in our study and pre-potent inhibition in Kapa & Erikson's study). Considering that -to our knowledge- no other study has investigated the relationship between the three core EFs (updating, inhibition and cognitive flexibility) using both verbal and non-verbal tasks and a wide range of oral language skills in 4–5-year-old children with and without DLD, further research is needed to supplement the findings of the present study.

In sum, the results of our study indicate that the three core EFs predicted oral comprehension in both TD and children with DLD. In addition, both verbal and nonverbal EFs predicted oral language skills in the TD group. On the contrary, besides verbal cognitive flexibility, nonverbal EFs (inhibition and updating) predicted oral language skills (oral comprehension) in children with DLD. The previous finding about the differential role of verbal and non-verbal EFs in oral language skills for the two groups of children could be explained by the fact that TD children have intact oral language skills unlike children with DLD that exhibit language deficits, which seem to interplay with cognitive skills such as EFs when measured with verbal tasks. Following that, it seems that only nonverbal EFs seem to support oral language skills in 4–5-year-old children with DLD. Last, the finding that both verbal and nonverbal cognitive flexibility was associated with oral language skills in children with DLD needs further investigation. One possible explanation for this may be the differences in the developmental trajectories of inhibition, updating (after the age of 6 months- Miyake et al., 2000) and cognitive flexibility (around the age of 4 years- Reinchenbach et al., 2016).

### *4.1. Educational and clinical implications*

The above findings could inform clinical practice both at the diagnosis and intervention level. More specifically, difficulties observed in updating and cognitive flexibility in children with DLD in our study indicate that these children may face difficulties in daily communication not only due to their language deficits but also due to executive functioning restraints. Thus, interdisciplinary groups of professionals need to assess both EFs and oral language skills of children. The fact that language development depends among others on EF skills suggests that interventions on preschool children with DLD should also target deficits in the three core EFs and enhance children's EF abilities. The earlier the children with DLD receive services and support the more likely they are to achieve successful language and learning skills (Guralnick, 2011).

## CRediT authorship contribution statement

**Eleni Kalliontzi:** Data curation, Formal analysis, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization, original draft, Writing – review & editing. **Asimina Ralli**: Conceptualization, Methodology, Formal analysis, Investigation, Resources, Writing – review & editing, Validation, Visualization, original draft, Supervision, Project administration. **Olympia Palikara:** Writing – review & editing, Project administration. **Petros Roussos**: Methodology, Validation, Writing – review & editing.

## Declaration of Competing Interest

We have no known conflict of interest to disclose.

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*What this paper adds*

While there is considerable research on EFs and their relationship with oral language skills in school aged children with and without

DLD, research on this topic for children under the age of 6 is still lagging. Further studies are needed to investigate the EF skills in younger age groups and the way they interact with oral language not only in TD children but also in children with DLD, in order to better understand their profile and support them. The present study adds new evidence about the plethora of affected areas of language (phonological and morphological awareness, oral language comprehension, vocabulary knowledge, narrative speech and pragmatics) and executive functioning (verbal and nonverbal updating and cognitive flexibility) in 4–5-year -old children with DLD compared to their TD peers. This evidence indicates that 4–5-year-old children with DLD may have not only language deficits but also cognitive ones, leading to theoretical and practical implications in terms of diagnostic and intervention procedures. Our findings also expand our knowledge on the relationship between EFs and oral language skills in very young children with and without DLD. More specifically, it was found that different EFs predicted specific oral language skills in each group of children suggesting that oral language abilities may depend on EFs. Therefore, appropriate modifications in the diagnostic and intervention procedures should be considered.

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