frontiers | Frontiers in Language Sciences

TYPE Original Research
PUBLISHED 19 June 2024
DOI 10.3389/flang.2024.1389301

Check for updates

OPEN ACCESS

EDITED BY
Erin K. Robertson,
Cape Breton University, Canada

REVIEWED BY
Susan E. Teubner-Rhodes,
Auburn University, United States
Arianna Zuanazzi,
New York University, United States

*CORRESPONDENCE
Sietske van Viersen
✉ S.vanViersen@uu.nl

†These authors have contributed equally to this work and share first authorship

RECEIVED 21 February 2024
ACCEPTED 24 May 2024
PUBLISHED 19 June 2024

CITATION
van Viersen S, Kerkhoff A and de Bree EH (2024) Looking beyond literacy and phonology: word learning and phonological cue use in children with and without dyslexia. *Front. Lang. Sci.* 3:1389301.
doi: 10.3389/flang.2024.1389301

Looking beyond literacy and phonology: word learning and phonological cue use in children with and without dyslexia

Sietske van Viersen[1,2]*†, Annemarie Kerkhoff[3]† and Elise H. de Bree[1,4]

[1]Department of Development and Education of Youth in Diverse Societies, Utrecht University, Utrecht, Netherlands, [2]Department of Special Needs Education, University of Oslo, Oslo, Norway, [3]Royal Auris Group, Rotterdam, Netherlands, [4]Research Institute of Child Development and Education, University of Amsterdam, Amsterdam, Netherlands

Introduction: This study investigated whether children with and without dyslexia differ in word learning and whether phonological cues to word class play a role. If children with dyslexia have difficulties with implicit learning, they might be less sensitive to such cues.

Methods: A group of 89 Dutch primary school children from Grades 3 to 6 participated in a word learning experiment, consisting of children with dyslexia ($n = 44$) and typically developing children ($n = 45$). Test items were four monosyllabic 'verb-like' nonwords (e.g., *voek*) and four bisyllabic 'noun-like' nonwords (e.g., *banijn*). They were presented as novel verbs or nouns in a two word sentence frame (e.g., "I voek" or "a voek"), paired with pictures of unfamiliar actions or objects. Nonwords were either consistent (e.g., "I voek," "a banijn") or inconsistent (e.g., "I banijn," "a voek") with word class. The word learning experiment consisted of a repetition, identification, and naming phase.

Results: Children with dyslexia showed lower word learning outcomes in the naming phase. However, phonological cues did not affect word learning in either group. Regression analyses indicated that phoneme awareness, receptive vocabulary, and nonword reading were predictors of word learning for all children.

Discussion: These findings indicate that Dutch children with dyslexia have more difficulty in recalling novel words, fitting in with their phonological difficulties. Phonological cues to word class did not contribute to word learning in either group.

KEYWORDS

dyslexia, oral word learning, phonological deficit, vocabulary, grammatical categorization

1 Introduction

Dyslexia is a specific learning disability that is characterized by severe and persistent difficulties in the acquisition of word-level reading and spelling skills, in the absence of sensory or neurological deficits and inadequate teaching (Peterson and Pennington, 2012). Having (a family risk of) dyslexia has been associated with lower performance in multiple areas and skills related to literacy (e.g., reading comprehension), including vocabulary development (Vellutino et al., 2004; Snowling and Melby-Lervåg, 2016). However, vocabulary *deficits* are not necessarily attested in children with dyslexia (Catts et al., 2005). To further understand the relationship between dyslexia, word learning, and vocabulary, the current study reports on a word learning experiment in children with and without dyslexia. Specifically, children were asked to repeat, identify, and produce novel words of low phonological complexity, with phonological cues that were either consistent or inconsistent with grammatical class (i.e., verb or noun). These phonological cues served to investigate whether children with and without dyslexia are sensitive to phonological cues and use them to support word learning.

Vocabulary learning forms the foundation for the development of higher-order language skills, such as morphological awareness and syntactic skills (e.g., Bates and Goodman, 2001; Torppa et al., 2010), as well as word reading and reading comprehension (Perfetti et al., 2010; Hulme et al., 2015; Suggate et al., 2018; van Viersen et al., 2018). Children with dyslexia have been found to show lower vocabulary levels already from very early ages (e.g., Scarborough, 1990; Torppa et al., 2010; Duff et al., 2015; van Viersen et al., 2017). However, when looking at the developmental pathways of these children, findings point toward a delay in vocabulary growth instead of deviant growth trajectories. Lower initial growth rates in both receptive and expressive vocabulary are followed by a weaker deceleration of growth toward the end of the growth spurt between the ages of 17 and 35 months, causing children to largely close the gap (van Viersen et al., 2017). The preschool/preliteracy vocabulary delay is thus not necessarily persistent.

Differences in vocabulary levels may arise again after reading onset, for example due to less exposure to print (Kush et al., 2005; Mol and Bus, 2011; Hulme and Snowling, 2016). However, such deficits are not attested across-the-board (e.g., Cunningham and Stanovich, 1991; van Viersen et al., 2018; Adlof et al., 2021). Furthermore, some studies have even suggested that vocabulary can be a protective or mitigating factor in older populations with dyslexia (Cavalli et al., 2016; Wiseheart and Altmann, 2018; van Viersen et al., 2019). These findings do not point toward a persistent vocabulary deficit in dyslexia.

Although findings on vocabulary outcomes in dyslexia are mixed, they seem consistent in that children with dyslexia display verbal word-learning difficulties (Thomson and Goswami, 2010; Alt et al., 2017, 2019; Kimppa et al., 2018; Adlof et al., 2021; Malins et al., 2021). Word learning requires constructing phonological representations that are connected to semantic representations (Gupta and Tisdale, 2009). For children with dyslexia, constructing these detailed phonological representations might be challenging: many children with dyslexia have a deficit in phonological processing, which has been proposed as an important underlying cause of dyslexia (see Ramus et al., 2003; Vellutino et al., 2004; Protopapas and Parrila, 2019, for a recent overview). This phonological deficit refers to the difficulties children with dyslexia have in segmenting, storing, reproducing, and manipulating phonological information. Indeed, studies have found relationships between phonological processing (such as phoneme awareness) and vocabulary size (e.g., Gathercole et al., 1999; Rispens and Baker, 2012; Abel and Schuele, 2014) as well as between phonological processing (nonword repetition) and novel word learning (Gathercole et al., 1999; Adlof and Patten, 2017).

The construction of detailed phonological representations is required for storing words in long-term memory, and long-term phonological representations in turn support short-term memory performance (Gathercole and Baddeley, 1990; Gathercole et al., 1999). For instance, typically developing children and children with dyslexia recall novel words better when they have phonologically dense neighborhoods. However, children with dyslexia show poorer overall levels of serial recall and are more likely to substitute novel words with real words (Thomson et al., 2005). Thomson and colleagues attribute such lexicalization errors of children with dyslexia to poorly specified phonological representations: these poorer representations make it harder to reconstruct decaying traces of novel words. Children with dyslexia have also been found to perform more poorly on visual-verbal paired associate learning (PAL) tasks, in which children are required to learn an association between a novel spoken word and a visual referent (Vellutino et al., 1995; Mayringer and Wimmer, 2000; Messbauer and de Jong, 2003; Elbro and Jensen, 2005; Warmington and Hulme, 2012). Performance is especially poor when children are asked to *produce* new labels (Litt et al., 2013; Kalashnikova and Burnham, 2016; Alt et al., 2017). These findings have generally been explained by difficulties with encoding and retrieving detailed phonological representations of novel words for the purpose of production, rather than general difficulties with paired associate learning *per se* (Litt and Nation, 2014). Constructing or maintaining novel phonological representations also depends on words in long-term memory and related factors such as word-likeness, neighborhood density, and phonotactic probability (e.g., Storkel, 2001, 2004).

The phonological form of a word needs to be learnt in order to acquire vocabulary. The phonological form of a word can also provide cues about the grammatical structure of a word. In English, for instance, nouns tend to have more syllables than verbs, and fewer consonants per syllable. Also, bisyllabic nouns are likely to have stress on the first syllable, while bisyllabic verbs have stress on the second syllable (Kelly, 1992). Corpus analyses also show that both English and Dutch child-directed speech contain phonological cues that can lead to categorization of verbs and nouns (Monaghan et al., 2007). If a language learner is sensitive to such phonological cues, this may facilitate word learning and strengthen the link between phonological and semantic representations.

There is evidence that children are sensitive to phonological "typicality" (Cassidy and Kelly, 2001; Fitneva et al., 2009). For instance, 3- to 6-year-old children were more likely to associate monosyllabic (i.e., verb-like) novel words with actions and three-syllabic (i.e., noun-like) words with objects (Cassidy and Kelly, 2001). Importantly, children were more likely to remember words in which phonology was consistent with word class. In a similar experiment, Fitneva et al. (2009) created eight noun-like and eight verb-like pseudowords. Seven-year-old children were presented with the novel word (e.g., "skik") and saw two pictures. They were told that the target referred either to an object (noun) or action (verb). In the consistent condition, the phonological cue agreed with the grammatical category (e.g., a noun-like nonword referring to an object), whereas in the inconsistent condition this was not the case (e.g., a noun-like nonword referring to an action). Children had to repeat the word and point to a picture. The results showed that in the initial phase of learning, children tended to choose a referent on the basis of phonological cues. In later stages of learning (after feedback), the phonological cue was found to have an effect on verb learning (i.e., children recalled verbs more accurately in the consistent condition). The study by Fitneva et al. (2009) thus indicates that phonological cues to word class can aid verb learning.

Similarly, in Dutch—the language under investigation in the current study—phonological cues have been found to distinguish between nouns and verbs: native adult speakers of Dutch were able to use phonological information to categorize nonword stems as nouns or verbs (Don and Erkelens, 2008). For instance, a bisyllabic target with final syllable containing schwa ("fallem") was likely to be categorized as a noun, whereas a monosyllabic target with a superheavy syllable ("pluig") was more likely to be categorized as a verb. Furthermore, on the basis of a corpus search, Don and Erkelens found that children between 2;0 and 3;6 rarely shifted words from nouns to verbs or vice versa. However, when they did shift, they changed the words to fit the phonological frame of the new category (i.e., from a noun to a verb using a phonological structure fitting a verb). In a computational study, segmental phonological cues could also successfully predict word class in Dutch (Durieux and Gillis, 2001). These findings suggest that these phonological cues may aid word learning in Dutch children.

It is yet unknown whether children with dyslexia are able to use phonological cues for word class to facilitate word learning. There are some indications that this could be problematic for this group of children. First, the phonological deficit implies the construction of less detailed phonological representations. This could hamper the implicit recognition of phonological patterns in relation to word categories. Second, pattern detection in general has been reported to be more difficult in children with dyslexia: studies on implicit and statistical learning have found that groups with dyslexia show lower outcomes than groups without dyslexia (e.g., Vicari et al., 2003; Pavlidou et al., 2010; see Lum et al., 2013, for a meta-analysis). In a recent word learning study, young adults with dyslexia were less able to use implicit knowledge of cross-situational statistics (Kligler et al., 2023). As a consequence of such an implicit learning deficit, children with dyslexia might be less sensitive to phonological or syntactic cues that could foster word learning through efficient categorization of new words.

At the same time, however, it could be that phonological pattern recognition is not problematic for children with dyslexia, as phonological output is affected more than recognition (e.g., Swan and Goswami, 1997; Ramus and Szenkovits, 2008), meaning that the patterns themselves might be recognized (implicitly). Furthermore, findings on statistical learning are far from conclusive, as relationships between statistical learning and literacy are not always attested (Schmalz et al., 2019; van Witteloostuijn et al., 2019, 2021) and not all studies report poorer statistical learning in people with dyslexia (Kelly et al., 2002; He and Tong, 2017; Staels and van den Broeck, 2017; West et al., 2021). Steeper learning curves have even been reported, suggesting more successful statistical learning for this group (Bennett et al., 2008). It is therefore an open question whether phonological cues are used for grammatical categorization to the same extent by children with and without dyslexia.

As far as we are aware, the only available evaluation of the use of cues for grammatical categorization in word learning of children with dyslexia comes from Gilliver and Byrne (2009). In three experiments, they looked into form class cues contributing to noun learning of English-speaking 4- to 5-year-olds. The reading risk status of these preschoolers was established on the basis of phonological awareness, letter recognition, the Rhyme and Final Sound test and vocabulary. In the first experiment, children had to repeat six (three-syllable) names for novel creatures and identify the correct picture in a recognition task (e.g., "Which one is schmalenork?"). There was a correlation between reading risk and recall; children with better recall had a lower risk for reading problems, but no such correlation was evident for recognition. In the second experiment, children were presented with (one/two-syllable) novel words, which could refer to a proper name ("Point to the one that is daxy") or a category name ("Point to the one that is a daxy"). Performance on this task was not related to reading risk status, which means children at risk were equally sensitive to form class cues (i.e., signaling the difference between proper names and category names). In the final experiment, children were presented with a short story in which novel proper and count nouns were presented, leading to a final sentence (e.g., "This is a fomp called zikt"). After the story, they were asked to recall both the proper names ("Do you remember who this creature is?") and the category name ("Do you remember what kind of creature this is?"). Children with a lower reading risk were better able to recall the targets and were better able to provide the word class.

Gilliver and Byrne (2009) take their findings to relate to the capacity of phonological and/or working memory: children at risk performed more poorly at recalling novel words, which requires more detailed phonological representations—and possibly greater processing demands—compared to recognition. Although the correlations between risk status and the learning outcomes (recall and word class accuracy) were weak-moderate only, these findings warrant further research on the ability of children with dyslexia to use cues for grammatical categorization and the type of cues they may be able to use. Furthermore, they speak to the influence of increasing task demands (e.g., production) and deficits in underlying skills that may affect the quality of phonological representations of new words.

The aim of the present study was to move beyond general aspects of literacy and phonology involved in word learning in children with and without dyslexia and assess to what extent word learning is influenced by phonological cues for grammatical class and (deficits in) phonological (literacy-related) and semantic (language-related) skills. Word learning was evaluated across different phases (repetition, identification, and naming). These different response types place different demands on the required level of detail of phonological representations of new words. The novel words were either consistent with their word class (a verb-like monosyllabic item in a verb frame, referring to an action; a noun-like bisyllabic item in a noun frame, referring to an object) or inconsistent (a noun-like item in a verb frame, referring to an action and vice versa). In the present study, the following research questions were addressed:

1. To what extent do children with and without dyslexia differ in the repetition, identification, and naming of novel words in word learning?
2. To what extent do phonological cues for word class (noun, verb) affect word learning in children with dyslexia and typically reading peers?
3. Which literacy- and language-related skills contribute to word learning, and are effects moderated by decoding ability?

Given that children with dyslexia are less able to form detailed phonological representations, we hypothesized lower performance of this group, specifically on the naming (production) of novel words during word learning (RQ1). In addition, for RQ2 we explored whether phonological cues might affect word learning outcomes for children with dyslexia. Previous research has found that phonological cues affect children's categorization of words (e.g., Fitneva et al., 2009). Such cues also seem to be available in Dutch (Don and Erkelens, 2008). However, so far, only one study has addressed the possible role of phonological cues to word class in children with a risk of reading problems. These findings did not point to different use of form class cues (Gilliver and Byrne, 2009). It is therefore an open question whether such cues play a different role for children with and without dyslexia. Finally, with respect to RQ3, we expected that both literacy-related (phonological awareness, rapid automatized naming, verbal memory, nonword reading) and language-related (vocabulary and sentence repetition) skills would contribute to word learning in children with and without dyslexia, especially when more detailed phonological representations are required (i.e., in the naming phase).

2 Materials and methods

2.1 Participants

The sample contained 89 Dutch primary school children (47.2% girls) from Grades 3 to 6 (aged 7.72 to 11.95 years) of 16 regular primary schools in the Netherlands. Children were recruited through informal networks and centers focused on diagnosis and treatment of dyslexia. Children participated after parental consent and the study was conducted following the ethical principles of the Faculty of Social and Behavioral Sciences of [redacted for anonymity]. The sample was divided into two groups: a dyslexia group ($n = 44$, 43.2% girls) consisting of children that had previously been diagnosed with dyslexia by a certified psychologist and a control group containing typical readers without learning difficulties ($n = 45$; 51.1% girls). Children in the dyslexia group were diagnosed with dyslexia following a response-to-intervention protocol (Kleijnen et al., 2008; de Jong et al., 2016) stating that children have to belong to a) the lowest 10% in reading (standard score ≤ 6; -1.35 *SD*), or b) the lowest 15% in reading *and* lowest 10% in spelling to get a diagnosis. All children were (re)assessed on their literacy skills and evaluated following the criteria above to confirm recruitment into the dyslexia or control group. Based on these criteria, two children originally recruited into the dyslexia group were excluded because they had an above average standard score on the word-reading task. Two children in the control group were excluded because their performance on the word-reading task fell within the lowest 10%. In addition, children with below average scores on vocabulary (standard score ≤ 85; -1 *SD*) and grammar (standard score ≤ 6; -1.35 *SD*) were excluded to minimize the influence of possible (comorbid) language deficits (see e.g., Alt et al., 2017). The background characteristics per group are displayed in Table 1.

Independent samples *t*-tests indicated that both groups differ significantly on literacy skills. In addition, both groups differ on a range of phonological skills generally impaired in dyslexia (i.e., phonological awareness [PA], alphanumeric rapid automatized naming [RAN], and verbal memory; Vellutino et al., 2004; Moll et al., 2014). The groups do not differ on general language skills, including vocabulary and grammar. As the group of children with dyslexia was significantly older than the control group, age was taken into account as a covariate where needed. The groups did not significantly differ in the division of sex ($\chi^2 = 0.56$, $p = 0.45$).

2.2 Instruments

2.2.1 Literacy

Word and nonword reading fluency were tested using the *Eén Minuut Test* (EMT; Brus and Voeten, 1999) and *Klepel* (van den Bos et al., 1994). Children were asked to read as many (non-)words as possible within the time limit of one (words) or two (nonwords) minutes. Item length increased from one to four syllables and both tasks contained 116 items. Raw scores were the number of correctly read words and 'nonwords' used in the analyses, while norm-based standard scores ($M = 10$, $SD = 3$) were used for the dyslexia assessment. Internal consistency is 0.90 for EMT and 0.92 for Klepel (Evers et al., 2012).

Word-level spelling was assessed with a short form of the *PI-dictee* (Geelhoed and Reitsma, 2000). In this spelling-to-dictation test children had to write down a target word that was presented in a sentence. The short form (see also van Viersen et al., 2016) contained eight sets of seven words categorized by (ir)regularity or spelling rule. The test was discontinued after six or more errors within the same set. Raw scores were the number of correctly spelled words, which were used in the analyses. The total score was computed (formula: + 7 *15/7) to derive percentile scores, which were used for the dyslexia assessment. Reliability of the full version varies between 0.90 and 0.93 (Evers et al., 2012).

2.2.2 Phonology

Phonological awareness was measured using two subtests of the *Fonemische Analyse Test* (FAT; van den Bos et al., 2011). In the first subtest, children had to delete a target phoneme from a spoken word and produce the resulting (non-)word (e.g., *kat* "cat" without /k/ is *at*). In the second subtest, children had to exchange the onset phonemes of two given words (e.g., *Moeder Gans* "Mother Goose" to *Goeder Mans*). Raw response times and accuracy scores were recorded and transformed into a number of correct answers per second score for the analyses. Norm-based standard scores were also derived per subtest ($M = 10$, $SD = 3$). Internal consistency of this computerized test is 0.93 (Evers et al., 2012).

Rapid automatized naming was assessed with the *Continu Benoemen and Woorden Lezen* (van den Bos and lutje Spelberg, 2007). Children had to name digits (i.e., 2, 4, 8, 5, and 9) and letters (i.e., d, o, a, s, and p) as quickly as possible. Each subtest contained 50 items, listed in five columns of 10 items. Outcomes were naming times in seconds per subtest and norm-based standard scores (M = 10, SD = 3). Raw naming times were transformed into number of items per second and combined into a mean alphanumeric RAN (digits and letters) score for the analyses. Internal consistency of the subtests varies between 0.79 and 0.87 (Evers et al., 2012).

TABLE 1 Background characteristics of the dyslexia and typical reader groups.

Variable	Dyslexia		Typical reader				Cohen's *d*	
	M	*SD*	*M*	*SD*	*t*	*df*	DYS vs. TR)	95% CI
Age in months	120.59	13.25	113.80	11.17	−2.62*	87	0.56	[0.13 to 0.98]
Word reading[a]	4.82	2.66	11.04	2.39	11.61***	87	−2.46	[−3.01 to −1.91]
Nonword reading[a]	5.82	2.56	11.24	3.01	9.15***	87	−1.94	[−2.44 to −1.43]
Spelling[b]	21.18	11.32	29.16	10.07	3.51**	87	−0.75	[−1.18 to −0.32]
PA[a]	7.31	2.17	11.88	2.82	7.74***	72	−1.81	[−2.31 to −1.32]
Alphanumeric RAN[a]	7.02	2.67	10.83	3.12	6.18***	87	−1.31	[−1.77 to −0.85]
Non-alphanumeric RAN[a]	8.13	2.43	10.40	5.33	2.58*	87	−0.55	[−0.97 to −0.12]
Verbal memory[a]	9.07	3.37	11.80	3.31	3.83***	86	−0.82	[−1.25 to −0.39]
Vocabulary[c]	101.11	10.92	104.98	10.31	1.72	87	−0.37	[−0.78 to 0.05]
Sentence repetition[a]	9.32	2.79	10.20	2.69	1.52	87	−0.32	[−0.74 to 0.10]

DYS, dyslexia; TR, typical reader; PA, phonological awareness; RAN, rapid automatized naming. Dyslexia was coded as 1 and TR was coded as 0 in the data, hence the opposite direction of the *t*-statistic compared to Cohen's *d*). [a] Standard scores (M = 10, SD = 3). [b] Percentile scores. [c] Standard scores (M = 100, SD = 15). *$p < 0.05$, **$p < 0.01$, ***$p < 0.001$.

2.2.3 Verbal memory

Verbal memory was measured using the Digit Span subtest of the Dutch *Wechsler Intelligence Scale for Children III* (WISC-III NL; Kort et al., 2005). The subtest consists of two parts, each covering 12 series of digits of increasing length. The first part is a verbal short-term memory (VSTM) task, in which children have to recall series of digits in forward fashion. The second task targets verbal working memory (VWM) and requires children to recall series of digits backwards. The raw score was the total number of correctly recalled sequences on both parts combined. Age-referenced standard scores ($M = 10$, $SD = 3$) were also available. Reliability of this subtest is sufficient to good (Kort et al., 2005; Cronbach's alpha = 0.64, test-retest reliability = 0.77).

2.2.4 Language

Receptive vocabulary was measured using the Dutch version of the *Peabody Picture Vocabulary Test* (PPVT-III NL; Dunn and Dunn, 2005). Children were verbally presented with a target word and had to choose the corresponding picture out of four alternatives. Target words were organized in sets of 12 words, with sets increasing in difficulty. The test starts at the entry set corresponding to the age of the child. Testing is discontinued after nine or more incorrect answers within one set. Raw scores are the number of correctly identified pictures, which are used in the analyses. Norm-based standard scores ($M = 100$, $SD = 15$) are also available. Reliability of the test is 0.94 (Dunn and Dunn, 2005).

Sentence repetition (measuring syntactic knowledge and VSTM) was assessed with the Recalling Sentences subtest of the Dutch *Clinical Evaluation of Language Fundamentals 4* (CELF-4 NL; Kort et al., 2010). Children were verbally presented with sentences of varying length and syntactic complexity that they had to recall and reproduce correctly. The subtest contains 31 sentences with a gradient scoring system (i.e., correct = 3; 1 error = 2; 2-3 errors = 1; 4+ errors = 0). The test starts with the item corresponding to the age of the child and is discontinued after five consecutive items without any points. Raw scores are used in the analyses. Norm-based standard scores ($M = 100$, $SD = 15$) are also available. Reliability of the test is sufficient to very good (Kort et al., 2010).

2.2.5 Word learning experiment

2.2.5.1 Procedure

A word-learning task was designed for this study. The task consisted of a first exposure phase, a repetition phase, a second exposure phase, an identification phase (phonological recognition), and a naming phase (phonological recall or production). In the *training* phase, the nonwords were presented as nouns or verbs in a phrase ("I verb" or "A noun"), paired with pictures of unfamiliar objects or actions. For instance, the novel verb "Ik voek" (*I voek*) was coupled to a novel action (e.g., a drawn picture of a girl covering her eyes). Children were told that they were going to learn eight new words and were encouraged to try and remember them. Next, two practice trials were provided, in which children heard a known noun or verb and were asked to repeat the word. The next phase was the *repetition* phase, in which children heard the eight novel words again and were asked to repeat them. In a second *exposure* phase, children heard all the words once again and were asked to try and remember them. Children were allowed to listen a second time if they wanted to. The subsequent *identification* phase was a three alternative forced-choice task, in which children were shown the same picture again and heard three nonwords: the correct one and two foils or distractor items. Children were asked to identify which of three words was the correct (newly learned) word. The nonword foils were items that they had not heard before, one monosyllabic and the other bisyllabic (e.g., for target "voek" the options were "guik," "safel," "voek"). Same-syllable foils had only minimal phonological overlap with the target word (i.e., one vowel or coda consonant for monosyllabic words and maximally two phonemes for bisyllabic words). However, the foils all had similar cues to word class (such as a schwa in the final syllable), as they were drawn from a larger list of suitable test items designed for this experiment. Children always received feedback on their response

("Yes, it was 'I voek'"), also when it was incorrect ("No, it was 'I voek', remember?"). After an incorrect choice, the item was always played again. During the *naming* phase, children were shown the pictures a final time and asked to produce the words.

2.2.5.2 Stimuli

The test items were mono- and bisyllabic nonwords that resembled Dutch singular nouns or verb stems (the list of test items and foils is provided in Appendix A). Targets and foils were all phonotactically legal and contained no consonant clusters. Noun-like and verb-like items were constructed based on classification studies by Don and Erkelens (2008), as discussed in the Introduction. Dutch speaking adults had a clear preference to treat bisyllabic stems as nouns (e.g., "a bodee" /bo:de:/) and monosyllabic stems as verbs (e.g., "I voek" /vu:k/), in line with the distribution of phonological cues in Dutch. In line with these studies, children are expected to consider the bisyllabic nonwords (e.g., "bodee") as more likely to be noun stems ("a bodee") than verb stems ("I bodee"). Pairing of items and pictures could be *consistent* (e.g., a noun-like item such as "bodee" paired with an object and presented as a noun "a bodee") or *inconsistent* (e.g., a noun-like item such as "bodee," paired with an action and presented as a verb "I bodee"; see Table 2). The same nonwords were presented as nouns or verbs depending on the version of the experiment. Four sets of eight test items and 16 foils were constructed, resulting in four different versions. All children heard four consistent and four inconsistent items, but the pairing was reversed in two versions (e.g., "voek" was presented as a noun for one participant [consistent] and as a verb for the next [inconsistent]). The other two versions only differed in the order of presentation (see Appendix A). The phonotactic probability of monosyllabic test items ($M = -1.51$) and bisyllabic test items ($M = -1.21$) was similar, based on the Dutch Phonotactic Frequency database (Adriaans, 2006). However, mean neighborhood density (ND) was higher for monosyllabic ('verb-like') test items ($M = 17.8$) than for bisyllabic ('noun-like') test items ($M = 2.0$). A density of 10 neighbors is commonly regarded a cut-off point for "high" ND (Gierut et al., 1999), which means that all four monosyllabic items were high ND targets. Previous studies suggest that offering sounds in high-frequency and high-density words facilitated phonological learning when treating children with phonological delays (e.g., Gierut and Morrisette, 2012).

2.2.5.3 Scoring

The experiment had three response phases (repetition, identification, and naming). One point was awarded per correct answer across these phases, adding up to a maximum score of 24. Relevant outcomes were proportion correct answers per response phase, the total proportion correct across the three phases, and the percentage of correct phonemes (PPC) in the repetition and production phase.

2.3 Procedure

Children were tested individually by trained and supervised graduate students during the spring semester. Testing took place at school during one test session that lasted for about 1 h with a few short breaks. The tasks, including the word-learning experiment, were part of a larger test battery and administered in a fixed order (see section 2.2). All tasks were conducted using a laptop, except for the spelling task that was paper-and-pencil-based. Findings were reported back to parents and clinical practices through a summary at the sample level.

2.4 Analyses

The analyses were conducted in several steps. First, differences between groups on the specific conditions in the experiment were further assessed using repeated-measures analyses with accuracy across the three phases (repetition, identification, and naming) as well as a total word learning score as outcome measures. Group was the between-subjects factor and consistency of the cues (i.e., consistent vs. inconsistent) was the within-subjects factor. In additional analyses, phonological cue for word class (i.e., monosyllabic or 'verb-like' vs. bisyllabic or 'noun-like') was considered as a second within-subjects factor. Pillai's Trace is reported in case of violation of assumptions. Partial eta-squared was reported as a measure of effect size (i.e., 0.01 = small, 0.06 = medium, 0.14 = large; Cohen, 1992). Age was included as a covariate.

Secondly, a moderation analysis was performed to assess how Language- and literacy-related skills contribute to word learning across reading levels. Relevant predictors were selected based on outcomes of the correlational analysis. The covariate (i.e., age), main effects for language- and literacy-related factors, and the moderator (i.e., nonword reading) were first included to assess what factors predict word learning. Subsequently, the interaction effects between the moderator and significant language- and literacy-factors were included to assess whether their effects on word learning are moderated by the level of decoding ability. Standardized regression coefficients (β) and explained variance were reported (R^2). The analyses were conducted with SPSS 27.0 (IBM Corp., 2020) using a two-tailed alpha-level of 0.05.

3 Results

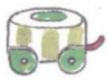
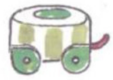
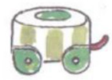
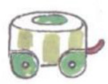
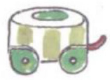
3.1 Data screening

An outlier analysis using z-scores (< -3.3 or > 3.3) showed that there were 11 minor univariate outliers. In addition, there were four multivariate outliers on the word-learning outcomes based on the Mahalanobis distance (i.e., $df = 4$, critical value = 18.467). However, the scores of these children on word reading and spelling measures, as well as underlying skills, were not multivariate outliers. All outliers were retained in the analysis because they concerned plausible raw scores. Missing data analysis showed that 0.16% of the data was missing (i.e., one score on VSTM and one on VWM, both in the dyslexia group).

Assessing the distributions of the variables indicated a deviation from normality on the spoonerism task. However, this was solved when the spoonerism and deletion tasks were combined into an overarching PA score. More importantly, there were strong ceiling

 10.3389/flang.2024.1389301

TABLE 2 Overview of phases and stimuli presentation in the word learning experiment.

	Repetition		Identification	Naming
Picture				
Phrase	(een) bodee[a]	(ik) voek[b]	bodee / gol / nado	?
	Consistent		Inconsistent	
				
	bodee	voek	voek	bodee

[a]Noun-like test item ("A noun"). [b] Verb-like test item ("I verb").

effects in the repetition and identification phases of the word-learning experiment. Therefore, outcomes of both phases were not taken into account in the analyses and the planned repeated-measures analysis on the different phases of the experiment was not conducted. Instead, PPC score (as the most sensitive outcome) and the proportion correct score for the naming phase were used as outcomes for the repeated-measures and moderation analyses, as they both adhered to normality assumptions. There were no signs of multicollinearity between variables. Descriptives of the individual and combined scores used in the analyses are provided in Table 3.

A *post-hoc* power analysis has been performed with G*Power (Faul et al., 2007) to indicate the achieved power with the given sample size. For the group comparisons, we had sufficient power (at least 0.80) to detect medium and large effects (Cohen's d of 0.5 or $\eta_p^2 = 0.06$). For the moderation analysis, performed on the full sample ($N = 89$), we had sufficient power to detect large, medium, and medium-small effects (up to $f^2 = 0.09$; 0.02 = small, 0.15 = medium, 0.35 = large, Cohen, 1988).

3.2 RQ 1 and 2: group comparisons on word learning outcomes

A repeated-measures analysis was conducted to assess whether the consistency of the cues (consistent vs. inconsistent) affected the PPC score in the production of learned words. The results showed no significant main effect of consistency, Pillai's Trace = 0.001, $F_{(1,86)} = 0.12$, $p = 0.73$, $\eta_p^2 = 0.001$, indicating that performance was comparable across consistent and inconsistent conditions. There was a main effect of group, $F_{(1,86)} = 12.62$, $p < 0.001$, $\eta_p^2 = 0.13$, indicating that the dyslexia group scored lower on the percentage correctly produced phonemes of learned words than the control group. The interaction between consistency and group was not significant, Pillai's Trace = 0.006, $F_{(1,86)} = 0.52$, $p = 0.48$, $\eta_p^2 = 0.006$, indicating that the dyslexia group obtained lower accuracy than the control group irrespective of consistency of the cues, while controlling for age. The results are displayed in Figure 1.

Additional analyses also taking phonological cue into account (i.e., monosyllabic or 'verb-like' vs. bisyllabic or 'noun-like') did not alter the findings (see Supplementary Figure S1). There were no significant two-way or three-way interactions and effect sizes were generally close to zero (except for the main effect of phonological cue, which was small). These results were the same when using the proportion of correctly produced words in the naming phase (see Supplementary Figures S2, S3). A quantitative inventory of children's errors in the naming phase (see Appendix B) shows that the distribution of phonological errors and all other error types was similar for the two groups (χ^2 [4, $N = 579$] = 2.68, $p = 0.612$).

3.3 RQ 3: contributions of literacy- and language-related abilities to word learning

Before the regression analyses for predicting word learning could be performed, correlations were checked (see Table 4). The correlation analysis showed that the word-learning phases are weakly to moderately related to each other, but only the production score is moderately related to the total word-learning score. The PPC scores for word learning are not correlated with each other, but the repetition PPC and production PPC scores are moderately related to their whole-word counterparts and moderately to strongly to the total word learning score. These correlations indicate that the PPC and whole-word scores for the naming phase measure partly distinct aspects of word learning. Regarding the relations of the word learning scores with the underlying skills, the correlations show that the patterns are not the

TABLE 3 **Descriptives for the word-learning outcomes, oral-language and literacy-related skills per group.**

Variable	Dyslexia ($n = 44$)				Typical Reader ($n = 45$)			
	M	*SD*	Min	Max	*M*	*SD*	Min	Max
Word learning (prop)								
Repetition	0.94	0.10	0.50	1.00	0.88	0.19	0.13	1.00
Identification	0.93	0.14	0.25	1.00	0.95	0.12	0.38	1.00
Production	0.21	0.25	0.00	1.00	0.29	0.25	0.00	0.88
Total	0.68	0.09	0.50	0.92	0.72	0.14	0.25	0.96
Word learning (PPC)								
Repetition	97.98	3.26	85.00	100.00	97.34	4.74	75.40	100.00
Production	32.38	19.30	0.00	75.00	46.71	22.71	0.00	93.80
PA[a]	0.17	0.08	0.04	0.49	0.30	0.12	0.08	0.64
RAN	1.67	0.31	1.09	2.34	2.02	0.40	1.11	3.14
VSTM[b]	7.21	1.70	4.00	12.00	8.36	2.00	4.00	12.00
VWM[b]	4.14	1.51	2.00	9.00	4.62	1.50	2.00	8.00
Vocabulary	117.52	10.32	101.00	149.00	117.42	10.53	98.00	137.00
Sentence repetition	58.45	13.58	21.00	84.00	60.18	13.14	32.00	83.00
Nonword reading	30.23	14.70	9.00	70.00	56.78	18.25	26.00	93.00

Prop, proportion; PPC, percentage phonemes correct; PA, phonological awareness; RAN, rapid automatized naming; VSTM, verbal short-term memory; VWM, verbal working memory. All reported values are raw scores used in the analyses. [a] Combined score of phoneme deletion and spoonerisms subtests. [b] $n = 43$ due to missing values for one participant from the dyslexia group.

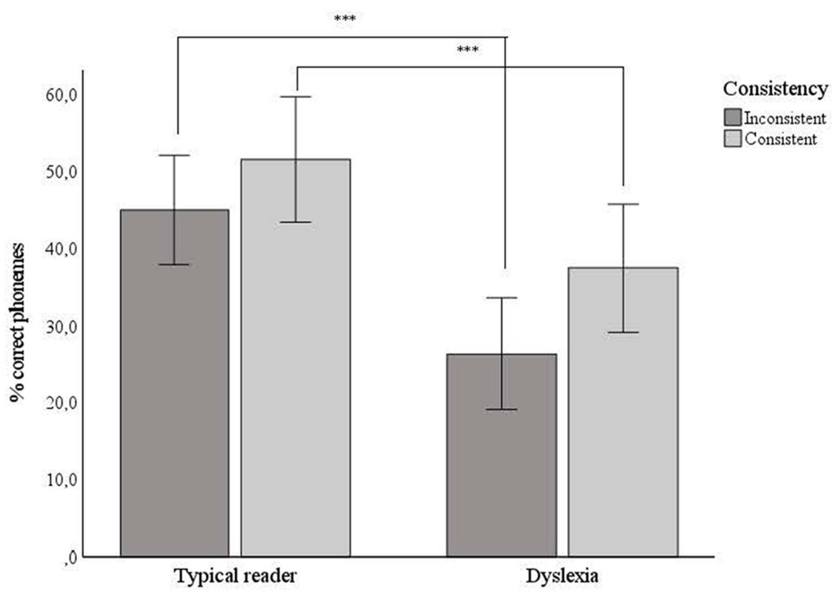


FIGURE 1
Group differences across consistency conditions for percentage phonemes correct (PPC) in the naming phase, with error bars and significance for main effect of group. $^{***}p < 0.001$.

same for the whole-word proportion and the PPC scores. Focusing on the scores from the naming phase (i.e., where ceiling effects played no role), the whole-word production score is only weakly related to PA, whereas the PPC production score shows moderate correlations with PA, vocabulary, and sentence repetition, and weak correlations with RAN and VSTM. This suggests that literacy-related skills (and deficits associated with dyslexia) as well as oral-language skills play a role in verbal learning of new words. Zero-order and partial correlations controlled for age show comparable patterns of results.

10.3389/flang.2024.1389301

TABLE 4 Zero-order and partial correlations between word learning phases and predictors.

Variables	1	2	3	4	5	6	7	8	9	10	11	12	13
Word learning													
1. Repetition[a]	–	0.42***	0.27*	−0.00	0.26*	−0.09	−0.20	−0.23*	−0.24*	−0.04	0.02	−0.30**	−0.17
2. Identification[a]	0.38***	–	0.29**	0.01	−0.10	0.01	−0.03	−0.00	−0.04	0.04	−0.06	−0.12	0.07
3. Production[a]	0.27**	0.29**	–	0.49***	0.05	0.51***	0.25*	−0.02	0.08	0.14	0.13	0.03	0.26*
4. Total[a]	0.04	0.01	0.49***	–	0.55***	0.76***	0.48***	0.08	0.16	0.25*	0.34**	0.22*	0.45***
5. Repetition PPC	0.34**	−0.11	0.07	0.56***	–	0.14	0.17	−0.12	−0.05	0.19	0.20	−0.05	0.11
6. Production PPC	−0.07	0.01	0.51***	0.76***	0.14	–	0.56***	0.22*	0.24*	0.19	0.44***	0.32**	0.54***
Underlying skills													
7. PA	−0.14	−0.03	0.26*	0.49***	0.21*	0.56***	–	0.45***	0.46***	0.42***	0.34**	0.42***	0.75***
8. RAN	−0.17	−0.01	−0.00	0.10	−0.07	0.23*	0.47***	–	0.36**	0.23*	0.11	0.20	0.65***
9. VSTM	−0.23*	−0.04	0.09	0.16	−0.04	0.24*	0.47***	0.37***	–	0.35**	0.25*	0.52***	0.36***
10. VWM	−0.04	0.04	0.14	0.25*	0.18	0.19	0.40***	0.22*	0.33**	–	0.11	0.25*	0.31**
11. Vocabulary	0.04	−0.05	0.13	0.29**	0.17	0.40***	0.35**	0.16	0.28**	0.06	–	0.34**	0.32**
12. Sentence rep	−0.26*	−0.12	0.04	0.21*	−0.03	0.32**	0.44***	0.22*	0.53***	0.22*	0.40***	–	0.28**
13. Nonword reading	−0.12	0.06	0.27*	0.46***	0.14	0.54***	0.75***	0.65***	0.36***	0.31**	0.28**	0.27*	–

PPC, percentage phonemes correct; PA, phonological awareness; A, alphanumeric; RAN, rapid automatized naming; NA, non-alphanumeric; VSTM, verbal short-term memory; VWM, verbal working memory. Zero-order correlations are displayed below the diagonal; partial correlations corrected for age are displayed above the diagonal. [a] Proportion correct (whole word). $^{*}p < 0.05$; $^{**}p < 0.01$; $^{***}p < 0.001$.

Subsequent regression analyses to assess which underlying cognitive skills contribute to verbal word learning consisted of a moderation analyses using stepwise multiple regression. The PPC score for the naming phase was taken as the outcome, as it was considered the most relevant indicator for the establishment of detailed phonological representations of novel words. The language- and literacy-related skills that were significantly related to the outcome were taken as predictors (see Table 4), age was included as a covariate, and nonword reading as the moderator.

In the first step, age, PA, RAN, VSTM, vocabulary, sentence repetition, and nonword reading were added (Model 1, see Table 5). The model was significant, $F_{(7,80)} = 8.55$, $p < 0.001$, and showed that PA ($p = 0.04$), vocabulary ($p = 0.01$), and nonword reading ($p = 0.03$) contributed a small but significant amount of variance to the percentage correctly produced phonemes during the naming phase. Together, the variables in the model explained 42.8% of the variance in the PPC score for word learning.

In the second step, the interactions between significant main effects (PA and vocabulary) and the moderator (nonword reading) were added to the model. However, the interaction between PA and nonword reading had to be excluded due to multicollinearity. The resulting model (see Model 2, Table 5) was significant, $F_{(8,79)} = 7.72$, $p < 0.001$, and indicated that vocabulary ($p = 0.02$) and nonword reading ($p = 0.03$) still contributed small but significant amounts of variance to the percent correctly produced phonemes during the naming phase. Yet, the interaction effect was not significant, indicating that the effect of vocabulary on verbal word learning is not different at various levels of nonword reading. Also, the fit of the model was not significantly better than the first model, $\Delta R^2 = 0.01$. $p = 0.22$. Together, the variables in Model 2 explained 43.9% of the variance in word learning.

Removing the non-significant effects of RAN, VSTM, and sentence repetition from Model 2 did not result in a significantly better fit ($\Delta R^2 = -0.02$, $p = 0.46$). Hence, the model with Age, PA, RAN, VSTM, vocabulary, sentence repetition, nonword reading, and the interaction between vocabulary and nonword reading was considered the final model (see Table 5). This model was preferred over Model 1 because of the significant main effects warranting testing for interactions, and the theoretical relevance of learning whether effects were different for children with different levels of nonword reading. Overall, taking the other variables into account, children with larger vocabularies, better phonological awareness, and better decoding ability are better able to form detailed phonological representations of novel words, as indicated by more correctly produced phonemes within learned words. These findings are similar when taking word reading as the moderator (see Supplementary Table S4). The only differences are that here the main effect of PA remains significant and the effect of vocabulary disappears in Model 2. In addition, interactions between word reading and both PA and vocabulary could be included in the model as there were no multicollinearity issues, but they were not significant.

4 Discussion

In this study, we aimed to further understand the relationship between dyslexia, word learning, and vocabulary. We tested whether children with dyslexia showed similar word learning outcomes as typical readers, and whether children with dyslexia were equally sensitive to phonological cues for word class. Monosyllabic ('verb-like') and bisyllabic ('noun-like') novel words were either presented as verbs (e.g., "I voek") or nouns (e.g., "a voek"), paired with a picture of an action (for verbs) or object (for nouns). The phonological structure of the targets was thus either consistent or inconsistent with word class (verb or noun). We first assessed whether differences existed between children with and without dyslexia on the repetition, identification, and/or naming of novel words in word learning (RQ1). Subsequently, we assessed to what extent the phonological cues to word class aided word learning in children with and without dyslexia (RQ2). Finally, we examined which literacy- and language-related skills contributed to word learning across reading levels (RQ3).

The hypothesis that children with dyslexia show lower performance in word learning specifically on the naming (production) of novel words was confirmed. Groups did not differ in repetition (immediate recall) or identification (phonological recognition) of the novel words. However, children with dyslexia had more difficulty in the naming (production) phase, in which they were asked to recall the target after a delay. Children with dyslexia made more errors overall, although the distribution of errors did not differ in the two groups.

Repetition and recognition are arguably less demanding than naming (production or recall). This finding is consistent with previous studies, in which word learning deficits are typically found for phonological recall but not immediate recall (repetition) or recognition (e.g., Gilliver and Byrne, 2009; Litt and Nation, 2014). As was found in previous studies, children with dyslexia generally perform well on the repetition of simple nonwords, only showing poorer performance when nonwords are three to four syllables long (de Bree et al., 2007). Moreover, children with dyslexia only seem to have difficulties with the identification of novel words when foils are phonologically highly similar, such as changes in final voicing (Alt et al., 2017). Importantly, processing demands increase when a higher level of phonological skills and detail of representations are required. For instance, in a sample of English-speaking second graders, Alt et al. (2017) found similar performance on novel word recognition in children with dyslexia compared to typically developing peers. Children with dyslexia showed lower performance on mispronunciation detection (i.e., requiring access to a detailed novel phonological form), but only when words were longer (four vs. two syllables) or phonologically similar to one another (similar sounding foils had different final phonemes, e.g., "gompav" vs. "gompaf"). In addition, when novel words had to be named (i.e., requiring production of the novel phonological form), children with dyslexia showed lower performance when words were more phonologically similar.

In a follow-up study, Alt et al. (2019) showed that naming deficits for children with dyslexia (7-9 years) were related to phonological rather than semantic learning, again showing effects of word length and phonological similarity. In these studies, as noted by Alt et al., the similar sounding foils may have influenced children's phonological representations in the naming task. In the current study, differences in naming accuracy were observed with short (one and two-syllable) targets, in the absence of similar sounding foils. The specific difficulties with naming (phonological

TABLE 5 Regression models for PPC production score with nonword reading as moderator.

Predictors	Model 1				Model 2			
	B	*SE*	95% CI	β	*B*	*SE*	95% CI	β
(Intercept)	39.66***	1.88	[35.93 to 43.39]		38.96***	1.95	[35.08 to 42.85]	
Age	−2.89	2.24	[−07.36 to 1.57]	−0.13	−2.58	2.25	[−7.06 to 1.90]	−0.12
PA	6.54*	3.12	[0.33 to 12.76]	0.29	6.09	3.13	[−0.15 to 12.33]	0.27
RAN	−3.21	2.59	[−8.36 to 1.94]	−0.14	−3.18	2.58	[−8.31 to 1.96]	−0.14
VSTM	−1.53	2.40	[−6.30 to 3.23]	−0.07	−1.66	2.39	[−6.42 to 3.09]	−0.08
Vocabulary	6.02*	2.38	[1.29 to 10.74]	0.27	5.77*	2.38	[1.04 to 10.50]	0.26
Sentence rep	1.98	2.39	[−2.76 to 6.73]	0.09	1.80	2.38	[−2.95 to 6.54]	0.08
Nonword reading	7.46*	3.40	[0.70 to 14.22]	0.33	7.65*	3.39	[0.91 to 14.40]	0.34
NWR*Vocabulary					2.42	1.97	[−1.49 to 6.33]	0.11

PPC, percentage phonemes correct; SE, standard error; CI, confidence interval; PA, phonological awareness; RAN, rapid automatized naming; VSTM, verbal short-term memory; NWR, nonword reading. $^{*}p < 0.05$. $^{***}p < 0.001$.

recall) suggest that phonological representations were sufficient for immediate recall (repetition) but were not maintained over a short period of time, as has been observed by others (Litt and Nation, 2014). However, it is noteworthy that we were still able to find differences between children with dyslexia and typical readers in the naming phase after repeated exposure (4–5 times) to the new words. It is conceivable that children with dyslexia are disadvantaged by a delay between exposure and naming, or by the exposure to foils in the identification phase. However, earlier studies also observed group differences in "fast mapping" or PAL procedures, in which a production probe is typically presented immediately after repeated exposure of a novel word (Litt et al., 2013; Kalashnikova and Burnham, 2016; Alt et al., 2017).

We did not find support for the hypothesis that children with dyslexia may benefit *less* from phonological cues for word class in word learning than their typical reading peers. Dutch children—with or without dyslexia—do not seem to show sensitivity to phonological cues for word class in word learning. This lack of sensitivity might reflect the fact that Dutch phonological cues for word class are probabilistic rather than deterministic. For instance, while bisyllabic items were all 'noun-like' (*mapier* - *papier* "paper"), monosyllabic items were more ambiguous (*voek* is similar to verb stems such as *zoek* "search" as well as monosyllabic nouns such as *boek* "book"). It is also possible that the nature of the word learning task (i.e., exposing children to consistent and inconsistent items in sentence frames) might have obscured any effect of phonological cues for word class. As we did not test children's initial 'guess' to word class for the novel words, we cannot determine whether phonological cues would have played a role *before* learning. A main effect of phonological cue was not found either, indicating that children performed similarly on the production of monosyllabic ('verb-like') and bisyllabic ('noun-like') targets, even though these differed in neighborhood density. It should be noted, however, that the effect size for this main effect was small (while other effect sizes were close to zero) and the current sample size provided limited power to detect such an effect as significant. Given earlier results for Dutch (Don and Erkelens, 2008), perhaps such cues are only used for initial categorization and easily overridden. In Dutch, morphological or syntactic cues might be more useful than phonological cues for word categorization (Erkelens, 2009). Given that words were offered in sentence frames ("a" vs. "I"), this information may have overridden the weak phonological cues. Fitneva et al. (2009) observed effects of consistency only on verb learning. As suggested by these authors, this fits computational analyses of English, which show that nouns benefit from distributional information while phonological cues are more useful for verbs (Monaghan et al., 2007). In sum, even if phonological cues could theoretically be used for word learning, they were not strong enough in our study to find substantial effects. There is no evidence to suggest that children with dyslexia are less sensitive to phonological cues for word class than typical readers. This also aligns with recent findings indicating that children with dyslexia do not show specific impairments in statistical learning (e.g., Schmalz et al., 2019; van Witteloostuijn et al., 2019; West et al., 2021).

The hypothesis that performance on word learning is explained by language- and literacy-related skills in both children with and without dyslexia was confirmed. Both oral language skills (receptive vocabulary) and literacy-related skills (phonological awareness and nonword reading) were found to contribute to word learning in the naming phase. These results are in line with previous findings that vocabulary and phonological representations are strongly related (Melby-Lervåg et al., 2012). It should, however, be stressed that our findings stem from concurrent data, and do not rely on a longitudinal study of the influence of phonology (phonological form and phonological cues) on word learning.

In sum, the current findings are in line with previous studies on the phonological deficit (Swan and Goswami, 1997; Ramus and Szenkovits, 2008) and studies that show phonological difficulties contribute to word learning (problems) in children with dyslexia (Thomson and Goswami, 2010; Litt and Nation, 2014; Alt et al., 2017, 2019; Adlof et al., 2021). Taken together, this study shows that retrieving and producing phonological forms of novel words is challenging for children with dyslexia. We found no evidence of an implicit learning deficit, as neither group used phonological cues for word class. Possibly, the lack of an additional impact of the phonological deficit on word categorization may act as a buffer for language acquisition. This indicates that word learning and word reading are important to consider as separate aspects in relation to dyslexia.

In future work, it would be interesting to assess the role of orthography in novel word learning of children with dyslexia. Children with dyslexia may benefit from orthography, although to a lesser extent than typical readers (Baron et al., 2018; Alt et al., 2019). Finally, it is unclear to what extent children would have benefited from more exposure to the novel words, as has been found for children with developmental language disorders (Gray, 2004). It is likely that children with dyslexia need more exposure to novel words to form sufficiently detailed and robust phonological representations.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving humans were approved by the Ethics Committee of Utrecht University. The studies were conducted in accordance with the local legislation and institutional requirements. Written informed consent for participation in this study was provided by the participants' legal guardians/next of kin.

Author contributions

SvV: Formal analysis, Methodology, Visualization, Writing – original draft, Writing – review & editing. AK: Conceptualization, Data curation, Investigation, Methodology, Project administration, Supervision, Writing – review & editing. EdB: Conceptualization, Data curation, Investigation, Methodology, Project administration, Supervision, Writing – review & editing.

Funding

The author(s) declare that financial support was received for the research, authorship, and/or publication of this article. Open access publication of this manuscript has been funded by the University of Oslo.

Acknowledgments

We would like to thank the students for their assistance in data collection and the children for their participation.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors and the reviewers. Any product that may be evaluated in this article, or claim that may be made by its manufacturer, is not guaranteed or endorsed by the publisher.

Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/flang.2024.1389301/full#supplementary-material

References

Abel, A. D., and Schuele, C. M. (2014). The influence of two cognitive-linguistic variables on incidental word learning in 5-year-olds. *J. Psycholing. Res.* 43, 447–463. doi: 10.1007/s10936-013-9264-4

Adlof, S. M., Baron, L. S., Bell, B. A., and Scoggins, J. (2021). Spoken word learning in children with developmental language disorder or dyslexia. *J. Speech Lang. Hearing Res.* 64, 2734–2749. doi: 10.1044/2021_JSLHR-20-00217

Adlof, S. M., and Patten, H. (2017). Nonword repetition and vocabulary knowledge as predictors of children's phonological and semantic word learning. *J. Speech Lang. Hearing Res.* 60, 682–693. doi: 10.1044/2016_JSLHR-L-15-0441

Adriaans, F. (2006). *PhonotacTools: A Tool for Computing Phonotactic Probabilities* [computer program]. Utrecht Institute of Linguistics OTS, Utrecht University.

Alt, M., Gray, S., Hogan, T. P., Schlesinger, N., and Cowan, N. (2019). Spoken word learning differences among children with dyslexia, concomitant dyslexia and developmental language disorder, and typical development. *Lang. Speech Hearing Serv. Schools* 50, 540–561. doi: 10.1044/2019_LSHSS-VOIA-18-0138

Alt, M., Hogan, T., Green, S., Gray, S., Cabbage, K., Cowan, N., et al. (2017). Word learning deficits in children with dyslexia. *J. Speech Lang. Hear. Res.* 60, 1012–1028. doi: 10.1044/2016_JSLHR-L-16-0036

Baron, L. S., Hogan, T. P., Alt, M., Gray, S., Cabbage, K. L., Green, S., et al. (2018). Children with dyslexia benefit from orthographic facilitation during spoken word learning. *J. Speech Lang. Hearing Res.* 61, 2002–2014. doi: 10.1044/2018_JSLHR-L-17-0336

Bates, E., and Goodman, J. C. (2001). "On the inseparability of grammar and the lexicon: Evidence from acquisition," in *Language Development. The Essential Readings*, eds. M. Tomasello and E. Bates (New York, NY: Blackwell), 134–162.

Bennett, I. J., Romano, J. C., Howard Jr J. H., and Howard, D. V. (2008). Two forms of implicit learning in young adults with dyslexia. *Annal. N. Y. Acad. Sci.* 1145, 184–198. doi: 10.1196/annals.1416.006

Brus, B. T., and Voeten, M. J. M. (1999). *Eén Minuut Test [One minute test]*. Boston, MA: Hartcourt Test Publishers.

Cassidy, K. W., and Kelly, M. H. (2001). Children's use of phonology to infer grammatical class in vocabulary learning. *Psychon. Bullet. Rev.* 8, 519–523. doi: 10.3758/BF03196187

Catts, H. W., Adlof, S. M., Hogan, T. P., and Ellis Weismer, S. (2005). Are specific language impairment and dyslexia distinct disorders? *J. Speech Lang. Hearing Res.* 48, 1378–1396. doi: 10.1044/1092-4388(2005/096)

Cavalli, E., Casalis, S., El Ahmadi, A., Zira, M., Poracchia-George, F., Cole, P., et al. (2016). Vocabulary skills are well developed in university students with dyslexia: evidence from multiple case studies. *Res. Dev. Disab.* 51, 89–102. doi: 10.1016/j.ridd.2016.01.006

Cohen, J. (1988). *Statistical Power Analysis for the Behavioral Sciences, 2nd Edn*. Hillsdale, NJ: Lawrence Erlbaum Associates, Publishers.

Cohen, J. (1992). A power primer. *Psychol. Bullet.* 112, 155–159. doi: 10.1037/0033-2909.112.1.155

Cunningham, A. E., and Stanovich, K. E. (1991). Tracking the unique effects of print exposure in children: associations with vocabulary, general knowledge, and spelling. *J. Educ. Psychol.* 83, 264–274. doi: 10.1037/0022-0663.83.2.264

de Bree, D., Rispens, E. J., and Gerrits, E. (2007). Non-word repetition in Dutch children with (a risk of) dyslexia and SLI. *Clin. Ling. Phonetic.* 21, 935–944. doi: 10.1080/02699200701576892

de Jong, S. D. N., de Bree, P. F., Henneman, E. H., Kleijnen, K., and Loykens, R. E. H. M., Wijnen, F. N. K. (2016). *Dyslexie: diagnostiek en behandeling. Brochure van de Stichting Dyslexie Nederland. [Dyslexia: Diagnosis and Treatment. Brochure of the Dutch Dyslexia Foundation].* Stichting Dyslexie Nederland (SDN)

Don, J., and Erkelens, M. (2008). Possible phonological cues in categorial acquisition: evidence from adult categorization. *Stu. Lang.* 32, 670–682. doi: 10.1075/sl.32.3.09don

Duff, F. J., Reen, G., Plunkett, K., and Nation, K. (2015). Do infant vocabulary skills predict school-age language and literacy outcomes? *J. Child Psychol. Psychiatr.* 56, 848–856. doi: 10.1111/jcpp.12378

Dunn, L. M., and Dunn, L. M. (2005). *Peabody Picture Vocabulary Test-III-NL [PPVT-III-NL]. (L. Schlichting, Trans.).* London: Pearson.

Durieux, G., and Gillis, S. (2001). "Predicting grammatical classes from phonological cues: An empirical test," in *Approaches to Bootstrapping*, eds. J. Weissenborn and B. Höhle (New York, NY: John Benjamins), 189–229.

Elbro, C., and Jensen, M. N. (2005). Quality of phonological representations, verbal learning, and phoneme awareness in dyslexic and normal readers. *Scand. J. Psychol.* 46, 375–384. doi: 10.1111/j.1467-9450.2005.00468.x

Erkelens, M. A. (2009). *Learning to Categorize Verbs and nouns: Studies on Dutch. Dissertation.* Dutch: LOT.

Evers, A., Egberink, I. J. L., Braak, M. S. L., Frima, R. M., Vermeulen, C. S. M., and van Vliet-Mulder, J. C. (2012). *COTAN Documentatie [COTAN Documentation].* Amsterdam: Boom Testuitgevers.

Faul, F., Erdfelder, E., Lang, A. G., and Buchner, A. (2007). G*Power 3: a flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behav. Res. Methods* 39, 175–191. doi: 10.3758/BF03193146

Fitneva, S. A., Christiansen, M. H., and Monaghan, P. (2009). From sound to syntax: phonological constraints on children's lexical categorization of new words. *J. Child Lang.* 36, 967–997. doi: 10.1017/S0305000908009252

Gathercole, S. E., and Baddeley, A. D. (1990). The role of phonological memory in vocabulary acquisition: a study of young children learning new names. *Br. J. Psychol.* 81, 439–454. doi: 10.1111/j.2044-8295.1990.tb02371.x

Gathercole, S. E., Frankish, C. R., Pickering, S. J., and Peaker, S. (1999). Phonotactic influences on short-term memory. *J. Exp. Psychol. Learning Memory Cognit.* 25, 84–95. doi: 10.1037//0278-7393.25.1.84

Geelhoed, J., and Reitsma, P. (2000). *PI-Dictee [PI-Dictation].* Springfield, IL: Swets Test Publishers.

Gierut, J. A., and Morrisette, M. L. (2012). Density, frequency and the expressive phonology of children with phonological delay. *J. Child Lang.* 39, 804–834. doi: 10.1017/S0305000911000304

Gierut, J. A., Morrisette, M. L., and Champion, A. H. (1999). Lexical constraints in phonological acquisition. *J. Child Lang.* 26, 261–294. doi: 10.1017/S0305000999003797

Gilliver, M. L., and Byrne, B. (2009). What's in a name? Preschoolers' noun learning performance in relation to their risk for reading disability. *Reading Writing* 22, 637–659. doi: 10.1007/s11145-008-9155-5

Gray, S. (2004). Word learning by preschoolers with specific language impairment. *J. Speech Lang. Hear. Res.* 47, 1117–1132. doi: 10.1044/1092-4388(2004/083)

Gupta, P., and Tisdale, J. (2009). Word learning, phonological short-term memory, phonotactic probability and long-term memory: towards an integrated framework. *Philos. Trans. Royal Soc. B Biol. Sci.* 364, 3755–3771. doi: 10.1098/rstb.2009.0132

He, X., and Tong, S. X. (2017). Quantity Matters: children with dyslexia are impaired in a small, but not large, number of exposures during implicit repeated sequence learning. *Am. J. Speech Lang. Pathol.* 26, 1080–1091. doi: 10.1044/2017_AJSLP-15-0190

Hulme, C., Nash, H. M., Gooch, D., Lervåg, A., and Snowling, M. J. (2015). The foundations of literacy development in children at familial risk of dyslexia. *Psychol. Sci.* 26, 1877–1886. doi: 10.1177/0956797615603702

Hulme, C., and Snowling, M. J. (2016). Reading disorders and dyslexia. *Curr. Opin. Pediatr.* 28, 731. doi: 10.1097/MOP.0000000000000411

IBM Corp. (2020). *IBM SPSS Statistics for Windows (Version 27.0) [Computer* software].

Kalashnikova, M., and Burnham, D. (2016). Novel word learning, reading difficulties, and phonological processing skills. *Dyslexia* 22, 101–119. doi: 10.1002/dys.1525

Kelly, M. H. (1992). Using sound to solve syntactic problems: the role of phonology in grammatical category assignments. *Psychol. Rev.* 99, 349–364. doi: 10.1037/0033-295X.99.2.349

Kelly, S. W., Griffiths, S., and Frith, U. (2002). Evidence for implicit sequence learning in dyslexia. *Dyslexia* 8, 43–52. doi: 10.1002/dys.208

Kimppa, L., Shtyrov, Y., Partanen, E., and Kujala, T. (2018). Impaired neural mechanism for online novel word acquisition in dyslexic children. *Sci. Rep.* 8:12779. doi: 10.1038/s41598-018-31211-0

Kleijnen, R., Bosman, A., de Jong, D., Henneman, P., Pasman, K., Paternotte, J., et al. (2008). *Diagnose en Behandeling van Dyslexie. Brochure van de Stichting Dyslexie Nederland [Diagnosis and Treatment of Dyslexia. Brochure of the Dutch Dyslexia Foundation].* Stichting Dyslexie Nederland (SDN).

Kligler, N., Yu, C., and Gabay, Y. (2023). Reduced implicit but not explicit knowledge of cross-situational statistical learning in developmental dyslexia. *Cognit. Sci.* 47:e13325. doi: 10.1111/cogs.13325

Kort, W., Schittekatte, M., Bosmans, M., Compaan, E. L., Dekker, P. H., Vermeir, G., et al. (2005). *Wechsler Intelligence Scale for Children III-NL (WISC III-NL).* London: Pearson.

Kort, W., Schittekatte, M., and Compaan, E. L. (2010). *Clinical Evaluation of Language Fundamentals-4 NL (CELF-4-NL).* London: Pearson.

Kush, J. C., Watkins, M. W., and Brookhart, S. M. (2005). The temporal-interactive influence of reading achievement and reading attitude. *Educ. Res. Eval.* 11, 29–44. doi: 10.1080/13803610500110141

Litt, R. A., de Jong, D., van Bergen, P. F. E., and Nation, K. (2013). Dissociating crossmodal and verbal demands in paired associate learning (PAL): What drives the PAL–reading relationship?. *J. Exp. Child Psychol.* 115, 137–149. doi: 10.1016/j.jecp.2012.11.012

Litt, R. A., and Nation, K. (2014). The nature and specificity of paired associate learning deficits in children with dyslexia. *J. Memory Lang.* 71, 71–88. doi: 10.1016/j.jml.2013.10.005

Lum, J. A., Ullman, M. T., and Conti-Ramsden, G. (2013). Procedural learning is impaired in dyslexia: evidence from a meta-analysis of serial reaction time studies. *Res. Dev. Disab.* 34, 3460–3476. doi: 10.1016/j.ridd.2013.07.017

Malins, J. G., Landi, N., Ryherd, K., Frijters, J. C., Magnuson, J. S., Rueckl, J. G., et al. (2021). Is that a pibu or a pibo? Children with reading and language deficits show difficulties in learning and overnight consolidation of phonologically similar pseudowords. *Dev. Sci.* 24:e13023. doi: 10.1111/desc.13023

Mayringer, H., and Wimmer, H. (2000). Pseudoname learning by German-speaking children with dyslexia: evidence for a phonological learning deficit. *J. Exp. Child Psychol.* 75, 116–133. doi: 10.1006/jecp.1999.2525

Melby-Lervåg, M., Lyster, S. A. H., and Hulme, C. (2012). Phonological skills and their role in learning to read: a meta-analytic review. *Psychol. Bullet.* 138, 322–352. doi: 10.1037/a0026744

Messbauer, V. C., and de Jong, P. F. (2003). Word, nonword, and visual paired associate learning in Dutch dyslexic children. *J. Exp. Child Psychol.* 84, 77–96. doi: 10.1016/S0022-0965(02)00179-0

Mol, S. E., and Bus, A. G. (2011). To read or not to read: a meta-analysis of print exposure from infancy to early adulthood. *Psychol. Bullet.* 137, 267–296. doi: 10.1037/a0021890

Moll, K., Ramus, F., Bartling, J., Bruder, J., Kunze, S., Neuhoff, N., et al. (2014). Cognitive mechanisms underlying reading and spelling development in five European orthographies. *Learn. Instr.* 29, 65–77. doi: 10.1016/j.learninstruc.2013.09.003

Monaghan, P., Christiansen, M. H., and Chater, N. (2007). The phonological-distributional coherence hypothesis: Cross-linguistic evidence in language acquisition. *Cognit. Psychol.* 55, 259–305. doi: 10.1016/j.cogpsych.2006.12.001

Pavlidou, E. V., Kelly, L. M., and Williams, J. M. (2010). Do children with developmental dyslexia have impairments in implicit learning? *Dyslexia* 16, 143–161. doi: 10.1002/dys.400

Perfetti, C., McKeown, M. G., and Kucan, L. (2010). "Decoding, vocabulary, and comprehension," in *Bringing Reading Research to Life*, eds. M. G., McKeown and L. Kucan (New York, NY: The Guilford Press), 291–303.

Peterson, R. L., and Pennington, B. F. (2012). Developmental dyslexia. *The Lancet* 379, 1997–2007. doi: 10.1016/S0140-6736(12)60198-6

Protopapas, A., and Parrila, R. (2019). Dyslexia: still not a neurodevelopmental disorder. *Brain Sci.* 9, 9–13. doi: 10.3390/brainsci9010009

Ramus, F., Rosen, S., Dakin, S. C., Day, B. L., Castellote, J. M., White, S., et al. (2003). Theories of developmental dyslexia: insights from a multiple case study of dyslexic adults. *Brain* 126, 841–865. doi: 10.1093/brain/awg076

Ramus, F., and Szenkovits, G. (2008). What phonological deficit?. *Q. J. Exp. Psychol.* 61, 129–141. doi: 10.1080/17470210701508822

Rispens, J., and Baker, A. (2012). Nonword repetition: the relative contributions of phonological short-term memory and phonological representations in children with language and hearing impairment. *J. Speech Lang. Hearing Res.* 55, 683–694. doi: 10.1044/1092-4388(2011/10-0263)

Scarborough, H. S. (1990). Very early language deficits in dyslexic children. *Child Dev.* 61, 1728–1743. doi: 10.2307/1130834

Schmalz, X., Moll, K., Mulatti, C., and Schulte-Körne, G. (2019). Is statistical learning ability related to reading ability, and if so, why? *Sci. Stu. Reading* 23, 64–76. doi: 10.1080/10888438.2018.1482304

Snowling, M. J., and Melby-Lervåg, M. (2016). Oral language deficits in familial dyslexia: a meta-analysis and review. *Psychol. Bullet.* 142, 498–545. doi: 10.1037/bul0000037

Staels, E., and van den Broeck, W. (2017). A specific implicit sequence learning deficit as an underlying cause of dyslexia? Investigating the role of attention in implicit learning tasks. *Neuropsychology* 31, 371–382. doi: 10.1037/neu0000348

Storkel, H. L. (2001). Learning new words: phonotactic probability in language development. *J. Speech Lang. Hearing Res.* 44, 1321–1337. doi: 10.1044/1092-4388(2001/103)

Storkel, H. L. (2004). Do children acquire dense neighborhoods? An investigation of similarity neighborhoods in lexical acquisition. *Appl. Psycholing.* 25, 201–221. doi: 10.1017/S0142716404001109

Suggate, S., Schaughency, E., McAnally, H., and Reese, E. (2018). From infancy to adolescence: The longitudinal links between vocabulary, early literacy skills, oral narrative, and reading comprehension. *Cognit. Dev.* 47, 82–95. doi: 10.1016/j.cogdev.2018.04.005

Swan, D., and Goswami, U. (1997). Phonological awareness deficits in developmental dyslexia and the phonological representations hypothesis. *J. Exp. Child Psychol.* 66, 18–41. doi: 10.1006/jecp.1997.2375

Thomson, J. M., and Goswami, U. (2010). Learning novel phonological representations in developmental dyslexia: associations with basic auditory processing of rise time and phonological awareness. *Reading Writing* 23, 453–473. doi: 10.1007/s11145-009-9167-9

Thomson, J. M., Richardson, U., and Goswami, U. (2005). Phonological similarity neighborhoods and children's short-term memory: Typical development and dyslexia. *Memory Cognition* 33, 1210–1219. doi: 10.3758/BF03193223

Torppa, M., Lyytinen, P., Erskine, J., Eklund, K., and Lyytinen, H. (2010). Language development, literacy skills, and predictive connections to reading in Finnish children with and without familial risk for dyslexia. *J. Learn. Disab.* 43, 308–321. doi: 10.1177/0022219410369096

van den Bos, K. P., and lutje Spelberg, H. C. (2007). *Continu Benoemen and Woorden Lezen (CBandWL) [Continuous Naming and Word Reading]*. North Holland: Boom testuitgevers.

van den Bos, K. P., lutje Spelberg, H. C., and de Groot, B. J. A. (2011). *Fonemische Analyse Test (FAT) [Phonemic Analysis Test]*. London: Pearson.

van den Bos, K. P., lutje Spelberg, H. C., Scheepstra, A. J. M., and de Vries, J. R. (1994). *De Klepel. Vorm A en B [Nonword reading test]*. London: Pearson.

van Viersen, S., de Bree, D., and de Jong, E. H. P. F. (2019). Protective factors and compensation in resolving dyslexia. *Sci. Stu. Reading* 23, 461–477. doi: 10.1080/10888438.2019.1603543

van Viersen, S., de Bree, D., Verdam, E. H., Krikhaar, M., Maassen, E., van der Leij, B., et al. (2017). Delayed early vocabulary development in children at family risk of dyslexia. *J. Speech Lang. Hearing Res.* 60, 937–949. doi: 10.1044/2016_JSLHR-L-16-0031

van Viersen, S., de Bree, D., Zee, E. H., Maassen, M., van der Leij, B. A., and de Jong, P. F. (2018). Pathways into literacy: the role of early oral language abilities and family risk for dyslexia. *Psychol. Sci.* 29, 418–428. doi: 10.1177/0956797617736886

van Viersen, S., Kroesbergen, E. H., Slot, E. M., and de Bree, E. H. (2016). High reading skills mask dyslexia in gifted children. *J. Learn. Disab.* 49, 189–199. doi: 10.1177/0022219414538517

van Witteloostuijn, M., Boersma, P., Wijnen, F., and Rispens, J. (2019). Statistical learning abilities of children with dyslexia across three experimental paradigms. *PloS ONE* 14:e0220041. doi: 10.1371/journal.pone.0220041

van Witteloostuijn, M., Boersma, P., Wijnen, F., and Rispens, J. (2021). The contribution of individual differences in statistical learning to reading and spelling performance in children with and without dyslexia. *Dyslexia* 27, 168–186. doi: 10.1002/dys.1678

Vellutino, F. R., Fletcher, J. M., Snowling, M. J., and Scanlon, D. M. (2004). Specific reading disability (dyslexia): What have we learned in the past four decades? *J. Child Psychol. Psychiatr.* 45, 2–40. doi: 10.1046/j.0021-9630.2003.00305.x

Vellutino, F. R., Scanlon, D. M., and Spearing, D. (1995). Semantic and phonological coding in poor and normal readers. *J. Exp. Child Psychol.* 59, 76–123. doi: 10.1006/jecp.1995.1004

Vicari, S., Marotti, L., Menghini, D., Molinari, M., and Petrosini, L. (2003). Implicit learning deficit in children with developmental dyslexia. *Neuropsychologica* 41, 108–114. doi: 10.1016/S0028-3932(02)00082-9

Warmington, M., and Hulme, C. (2012). Phoneme awareness, visual-verbal paired-associate learning, and rapid automatized naming as predictors of individual differences in reading ability. *Sci. Stu. Read.* 16, 45–62. doi: 10.1080/10888438.2010.534832

West, G., and Hulme, C., and Melby-Lervåg, M. (2021). Is a procedural learning deficit a causal risk factor for developmental language disorder or dyslexia? A meta-analytic review. *Dev. Psychol.* 57, 749–770. doi: 10.1037/dev0001172

Wiseheart, R., and Altmann, L. J. (2018). Spoken sentence production in college students with dyslexia: working memory and vocabulary effects. *Int. J. Lang. Commun. Disorders* 53, 355–369. doi: 10.1111/1460-6984.12353