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Understanding variation in prospective poor decoders: A person-centred approach from kindergarten to Grade 2

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In the present study, we aimed to clarify variation in prospective poor decoders by studying the development of their word decoding skills during the first 1½ years of formal reading education and their unique pre-reading profiles before the onset of formal reading education. Using structural equation modelling and a factorial mixed model analysis of variance (ANOVA), we found autoregression and growth in the word decoding efficiency of prospective poor decoders ($n = 90$) and matched prospective adequate decoders ($n = 90$) in first and second grade. However, the gap between the two groups widened over time. Next, we zoomed in on the group of poor decoders by retrospectively studying their individual variation regarding cognitive and linguistic pre-reading skills. Using latent profile analysis, we found three distinct pre-reading profiles: (1) Poor PA, Letter Knowledge, RAN, and Verbal STM; (2) Poor PA and Letter Knowledge; and (3) Poor RAN. Together, these findings suggest that reading difficulties emerge at the intersection of multiple risk factors which can be detected in kindergarten, and that these reading problems persist throughout early reading education.

This manuscript is based on data previously collected for the doctoral dissertation of Moniek M. H. Schaars and reported on in publications by Moniek M. H. Schaars, Eliane Segers, and Ludo Verhoeven.

KEYWORDS

dyslexia, phonological awareness, rapid naming, reading fluency, word decoding

1 | INTRODUCTION

For most children, word decoding—the skill of mapping spoken language units to written units—develops progressively throughout formal reading education in the early grades of primary school (e.g., Landerl & Wimmer, 2008). However, some children have severe and persistent difficulties decoding words from the very beginning, despite opportunity and instruction. Children with poor decoding skills are at a higher risk for developing emotional and behavioural problems and are less likely to attain high educational and income levels later in life than their adequately reading peers (e.g., McLaughlin et al., 2014). However, possible disorders in learning to read, like dyslexia, can only be diagnosed after a period of reading instruction (American Psychiatric Association, 2013). In the Netherlands, dyslexia assessment is conducted halfway through Grade 2 at the earliest (Verhoeven, 2019), taking into account the persistency criterium for dyslexia defined in DSM-V (, 2013). It remains unclear whether poor decoders develop similarly during these first few school years, or if their developmental trajectories vary. The present study, therefore, retrospectively analysed the development of word decoding skills in Dutch-speaking prospective poor decoders and matched prospective adequate decoders during the first 1½ years of formal reading education. In addition, prior research has shown that an interplay of cognitive and linguistic factors influences the progression of children's reading development (e.g., Schaars et al., 2017b; Wimmer et al., 2000; Zoubrinetzky et al., 2014). These factors interact in various ways, indicating that the population of poor decoders is not homogeneous, and that reading difficulties could be accounted for by different combinations of factors. A better understanding of the profiles that exist in this specific population, before formal reading education starts to exert its influence, is relevant for early identification of prospective poor decoders and for the ways in which we approach reading difficulties in individual children. The present study thus also aimed to uncover the profiles of pre-reading skills present in a group of prospective poor decoders.

1.1 | Development of word decoding skills

Word decoding efficiency is the number of printed words one can sound out in a certain amount of time (Seidenberg, 2017). The development of word decoding skills over the course of formal reading education can be studied at the group level and at the individual level (Bornstein et al., 2017). Regarding word decoding development at the group level, research has shown that the word decoding performance of a group of children improves as they participate in formal reading education and automatise their reading skills through practice (Landerl & Wimmer, 2008). Regarding development at the individual level, studies have found that children's performance on word decoding tasks at an earlier timepoint predicts later word decoding performance (autoregression; e.g., Compton, 2000; Landerl & Wimmer, 2008; Schaars et al., 2017a, 2017c). This suggests that children who perform relatively well on word decoding tests in the lower grades will continue to perform well, and that those who perform poorly at a young age are at a higher risk of continuing to perform poorly. In the meta-analysis by Pfost et al. (2014), this pattern is referred to as a widening achievement gap—also known as the Matthew effect (Stanovich, 1986). However, Pfost et al. (2014) also found evidence for a decreasing achievement gap and for stable achievement differences. In sum, it is not yet clear what early word decoding development looks like for young children who develop later reading problems (henceforth referred to as ‘prospective poor decoders’). The reading history and individual characteristics of Dutch prospective poor decoders in the period prior to formal intervention and diagnosis—at the earliest in Grade 2 in the Netherlands—have received little attention in the international literature, although this knowledge contributes to the identification and remediation of reading difficulties (e.g., Tilanus et al., 2016; Tilanus et al., 2019). Furthermore, prior studies have predicted the reading development of young children with a familial risk for dyslexia (e.g., Schaars et al., 2017b), but little is known about the individual developmental paths of the children who indeed become poor decoders. More insight into the emergence of word decoding difficulties compared to adequate reading development will contribute to our knowledge of the process of learning to read and the difficulties children can encounter during this process. The first aim of our study was thus to examine word decoding development over the first 1½ years of formal reading education for children who turn out to read poorly in Grade 2, compared to peers with adequate reading skills in Grade 2.

1.2 | Pre-reading skills

The process of learning to read is determined by several cognitive and linguistic skills. These skills predict both concurrent (e.g., Landerl et al., 2013; Melby-Lervåg et al., 2012; Tijms, 2004) and future word decoding abilities (e.g., de Jong & van der Leij, 2003; Lyytinen et al., 2004). It comes as no surprise that these skills are often impaired in poor decoders (e.g., Niileksela & Templin, 2018; Zoubrinetzky et al., 2014).

Across languages, the key predictors of reading development and reading problems are phonological awareness (PA) and rapid automatized naming (RAN; Landerl et al., 2013; Moll et al., 2014). PA is necessary for discovering the alphabetic principle and for decoding unfamiliar words (de Jong & van der Leij, 2003). It is closely related to the predictor grapheme-to-phoneme knowledge (Landerl & Wimmer, 2008). RAN, also referred to in the literature as naming speed, serial rapid naming, or lexical retrieval, contributes to the automaticity of grapheme-to-phoneme mappings and thus to the speed of word decoding (Landerl & Wimmer, 2008). The double-deficit hypothesis proposes that poor decoders are impaired in both PA and RAN (Wolf & Bowers, 1999). However, in relatively transparent orthographies such as Dutch, with consistent grapheme-to-phoneme mappings, poor decoders are often characterised by poor RAN and low word decoding *efficiency*, and to a lesser extent by poor PA, poor grapheme-to-phoneme knowledge, and low word decoding *accuracy* (Landerl et al., 2019; Wimmer et al., 2000).

Next to PA, RAN, and grapheme-to-phoneme knowledge, other predictors of reading development have been identified. Short-term memory (STM), generally split into verbal STM and visual STM (Alloway et al., 2006), helps children to mentally maintain strings of, respectively, phonemes and graphemes during word decoding (van den Boer et al., 2013). This is especially useful in orthographies with multi-letter graphemes like Dutch (see also Bosse & Valdois, 2009). Kibby (2009b) argued that verbal STM predominantly operates while decoding novel words that are not yet stored in the mental lexicon of the long-term memory. This skill is important for children just starting to learn to read. Visual STM provides a clear-cut measure of STM without the interference of implicit phonological processing tasks (Melby-Lervåg et al., 2012). Some studies have found visual STM to be related to word decoding abilities (e.g., Howes et al., 2003; Van den Boer et al., 2013) whereas others have not (e.g., Kibby, 2009a).

Finally, vocabulary knowledge can help children recognise the words they are sounding out and can thereby facilitate the process of word decoding (Kirby et al., 2008). However, it can be argued that vocabulary may be more important for the development of word decoding skills in opaque orthographies than in transparent orthographies, because of the several pronunciation possibilities for graphemes (see Krepel et al., 2021; Schaars et al., 2017c).

Research has found indications for individual variation in the RAN, PA, grapheme-to-phoneme knowledge, verbal STM, visual STM, and vocabulary of poor decoders (Snowling & Hulme, 2021; Wimmer et al., 2000; Zoubrinetzky et al., 2014). An optimal mix of these skills is believed to foster adequate word decoding skills, whereas a less optimal mix is believed to hamper word decoding development (Compton, 2000). Mastery of certain pre-reading skills has also been found to predict responsiveness to word decoding intervention for children with dyslexia (Tilanus et al., 2016). So far, multiple studies have used top-down approaches to determine subtypes of poor decoders based on their compositions of these skills (e.g., Shany & Share, 2010; Wimmer et al., 2000), but it is not yet clear whether this heterogeneity is present before children formally learn how to read. Schaars et al. (2017b) recommended retrospectively studying the characteristics of children with reading difficulties. From a theoretical standpoint, exploring the heterogeneity in pre-reading skills among Dutch prospective poor decoders will contribute to the advancement of multifactorial risk-resilience models (Catts & Petscher, 2021). From a practical perspective, our findings may aid the development and improvement of interventions to better address the individual needs of young children facing later reading difficulties, by taking their pre-reading profiles into account.

Most research on reading development has used variable-centred approaches, like regression analyses. These approaches assume that groups are homogeneous and lead to more general conclusions about associations between variables. In contrast, person-centred approaches like latent profile analysis (LPA) assume that groups are heterogeneous in how predictors and outcome variables are related (Catts & Petscher, 2021; Laursen & Hoff, 2006). Taking the heterogeneity among poor decoders into consideration is relevant for both scientific and practical purposes. The second aim of the present study was thus to identify the pre-reading profiles present in a group of prospective poor decoders in kindergarten using LPA.

1.3 | The present study

In the present study, we aimed to retrospectively investigate early characteristics of Dutch children with decoding difficulties in Grade 2 through the following research questions: (1) How do the word decoding skills of prospective poor decoders develop during the first 1½ years of formal reading education compared to matched prospective adequate decoders? and (2) Which pre-reading profiles can be found among prospective poor decoders? To answer the first question, we studied the development of word decoding efficiency of a cohort of prospective poor and adequate decoders in Grades 1 and 2 at both the group level and the individual level. The children were selected from a representative sample of 973 Dutch children that were followed throughout early reading education. For the second research question, we retrospectively analysed how the pre-reading skills of the prospective poor decoders clustered into profiles in kindergarten. Combining variable-centred and person-centred approaches provided us with complementary perspectives on reading development and allowed us to gain a better understanding of this complex topic (Laursen & Hoff, 2006).

Regarding the first research question, we hypothesised that the word decoding skills of prospective poor decoders and prospective adequate decoders would improve over time. In both groups, we expected to find autoregression in the word decoding development at the individual level. However, we expected the prospective poor decoders to develop at a slower pace than the prospective adequate decoders, leading to a growing gap between the two groups as reading instruction progressed.

Concerning the second research question, we expected to find at least two profiles, each characterised by a different makeup of cognitive and linguistic pre-reading skills, pointing to heterogeneity in the group of prospective poor decoders before the start of formal reading education. We hypothesised that one of these profiles would be characterised by low RAN skills and another to be characterised by low scores on both RAN and PA. As poor decoding in Dutch is mainly characterised by low efficiency, we did not hypothesise a profile with solely poor PA skills. Furthermore, we expected at least one profile to additionally include low verbal and/or visual STM skills.

2 | METHODS

2.1 | Participants

For the present study, data were selected from a larger data set ($n = 973$), collected between 2013 and 2016 by Schaars et al. (2017c) for a longitudinal project on literacy development. As part of the larger project, cognitive and linguistic skills were assessed in kindergarten. Word decoding skills were measured halfway through Grade 1, at the end of Grade 1, and halfway through Grade 2 using a standardised word decoding test.

We selected a purposive sample of poor decoders ($n = 91$) from the data set, all of whom obtained scores within the 10th percentile on the word decoding test at the third timepoint (halfway through Grade 2). This cut-off, although critically discussed as arbitrary (e.g., Ozernov-Palchik et al., 2017; Protopapas, 2019), is used in Dutch educational and clinical settings to identify poor decoders (Tijms et al., 2021), and thus meaningful for the practical implications and scientific comparability of our results. We specifically aimed to study the early developmental trajectories of these eventual poor decoders in hindsight, rather than follow at-risk children from Grade 1 onwards.

One child was excluded from analysis because of multiple missing values. The final sample of poor decoders contained 90 children from 28 different schools. Analysis in G*Power software affirmed that a sample size of 90 was sufficient to obtain a power of 0.80 for the analyses of development (Field, 2013). This means that with a sample size of 90, there would be an 80% chance or higher that the effects we found are true. Ninety children with adequate decoding skills (>10th percentile) at the third timepoint were matched pairwise to the sample of poor decoders on—in order of priority—school, SES, home language, and gender. An independent samples *t*-test revealed that the two groups did not differ on Raven's Coloured Progressive Matrices (CPM), $t(177) = -0.229$, $p = 0.82$), indicating that word decoding differences were not related to non-verbal reasoning abilities.

In the first part of our analyses, word decoding development of all 180 children was studied across three timepoints. In the Netherlands, the completion of three consecutive national standardised word decoding tests is a prerequisite for formal diagnostic testing (Tijms et al., 2021), as an indication of the persistency of reading problems. Furthermore, with three measurements, development can be determined at both the group level and the individual level (Bornstein et al., 2017). In the second part, we retrospectively analysed the kindergarten pre-reading profiles of the 90 poor decoders.

All children had received formal reading education through the highly protocolised phonics-based instructional programme *Veilig Leren Lezen* [Learning to Read Safely] (Mommers et al., 2003) in Grade 1. All levels of socioeconomic status (SES)—as indicated by the educational attainments of the children's primary caretakers (Centraal Bureau voor de Statistiek, 2013)—were represented in the sample (see Table 1). The distribution of SES and the percentage of children with a home language other than Dutch in both groups were similar to the original data set (16.9%) and representative for the Netherlands in 2013 (Centraal Bureau voor de Statistiek, 2013; see Table 1 and Appendix A).

2.2 | Instruments

2.2.1 | Word decoding measures

Word decoding skills were measured using a standardised test consisting of three cards of words (Drie-Minuten-Toets [Three-Minute Test]; Krom et al., 2010). Each card contained words that were orthographically

TABLE 1 Descriptive statistics for poor and adequate decoders.

Characteristics	Poor decoders	Matched adequate decoders
Gender	62.2% male	55.6% male
Mean age in kindergarten in years (SD)	6.25 (0.39)	6.16 (0.35)
Mean SES (SD)	3.05 (0.84)	3.03 (0.87)
Home language other than Dutch	20.0%	14.4%
Raven's CPM (SD)	27.22 (4.41)	27.39 (5.15)

Abbreviations: CPM, Coloured Progressive Matrices; SES, socioeconomic status.

more complex than those on the previous card (Card 1: 150 consonant-vowel-consonant [CVC] words, Card 2: 150 CCVC words, Card 3: 120 polysyllabic words), of which children were to read as many as possible in 1 min. Word decoding efficiency was calculated as the sum of the number of correctly read words in 3 min. The present study used the efficiency scores from halfway through Grade 1 (WD_1), the end of Grade 1 (WD_2), and halfway through Grade 2 (WD_3). It must be noted that at timepoint WD_1, when children had just started formal reading education, only the first two cards were administered (Krom et al., 2010). To facilitate the analyses of development, we transformed the narrower scale of WD_1 to match the wider scales of WD_2 and WD_3 as suggested by Little (2013). The internal consistency of the word decoding tasks was excellent (Cronbach's α 0.96 for Cards 1 and 2 at WD_1 and 0.97 for all three cards at WD_2 and WD_3; Krom et al., 2010).

2.2.2 | Pre-reading measures

Tasks measuring PA, grapheme-to-phoneme knowledge, RAN, verbal STM, visual STM, and vocabulary were administered in kindergarten. These tasks were all found to have sufficient internal consistencies (Cronbach's α between 0.77 and 0.95). All tasks contained practice items, except for the grapheme-to-phoneme knowledge task, because this task assessed children's existing knowledge.

Phonological awareness

PA was measured using two tasks. In the phoneme isolation task, children were presented with 10 spoken monosyllabic CVC-structured words and were asked to sound out the first phoneme (e.g., *s*oup). The number of correctly named first phonemes was scored.

The word segmentation task assessed more complex PA skills. Children were asked to segment 10 spoken words of increasing complexity into phonemes (e.g., s-ou-p). This task was discontinued after five consecutive incorrect responses and the number of correctly segmented words was scored.

Grapheme-to-phoneme knowledge

In this task, children were presented with a page of 34 lowercase Dutch graphemes and were asked to sound out the corresponding phonemes they knew. The number of correct grapheme-to-phoneme mappings was scored.

Rapid automatized naming

Children were presented with a page containing 132 randomly repeated images of five different objects (saw, pot, thumb, pants, and tent) and were asked to name as many images as possible in 1 min. The RAN score consisted of the number of correctly named images in 1 min.

Verbal STM

Children were asked to repeat 20 spoken pseudowords of increasing complexity (from one to four syllables, e.g., pronkel). The task was discontinued after five consecutive incorrect responses and the number of correctly repeated pseudowords was scored.

Visual STM

Children were presented with series of pictures of objects or animals for 5 s, after which they were asked to arrange the pictures in the order they had seen. The task contained 15 series of an increasing number of pictures, ranging from two to five. The task was discontinued after three consecutive incorrect series and the number of correct series was scored.

Vocabulary

Children were presented with pictures and corresponding sentences, which they were asked to finish using one word (e.g., This is a *zipper*) (Taaltoets Allochtone Kinderen [Language Test for Foreign Children]; Verhoeven et al., 1986). The task was discontinued after five consecutive incorrect responses and the number of correctly finished sentences was scored.

2.3 | Procedure

All tasks were individually administered in a quiet room at school during school hours (see Schaars et al., 2017c). The kindergarten sessions lasted about 30 min and followed a fixed order of pre-reading tasks. The word decoding tasks in Grades 1 and 2 were administered as part of regular standardised testing procedures. The participants and data were treated in accordance with institutional guidelines and APA ethical standards. Informed passive consent was obtained from the parents of the participating children (see Schaars et al., 2017c).

2.4 | Data analysis

Eight children (<5%) had missing values on one of the word decoding variables due to absence. For the analyses in Mplus (version 8.7), these values were handled using maximum likelihood estimation with robust standard errors. In IBM SPSS Statistics (version 28), the missing values were replaced using expectation maximisation (Allen et al., 2014).

2.4.1 | Development

To study word decoding development at the group level, a factorial mixed model analysis of variance (ANOVA) was conducted in SPSS, with time (WD_1 vs. WD_2 vs. WD_3) as the within-subjects factor and group (poor vs. adequate decoders) as the between-subjects factor. The Shapiro–Wilk, F_{max}, Box's, Mauchly's, and Levene's test statistics were used to test the assumptions of normality, homogeneity of variance, equality of covariance, and sphericity. Some assumptions were not met, but a mixed model ANOVA with moderate to large and equally sized samples is robust against these violations (Allen et al., 2014). For the development at the individual level, path analyses were conducted in Mplus, using the word decoding scores at the three timepoints (WD_1, WD_2, and WD_3). Model fit was evaluated using multiple indices, following the rules of thumb as specified by Geiser (2013).

2.4.2 | Pre-reading profiles

To detect the pre-reading profiles in the group of prospective poor decoders, LPAs were conducted in Mplus, using the seven pre-reading tasks (first phoneme isolation, word segmentation, grapheme-to-phoneme knowledge, RAN, verbal STM, visual STM, and vocabulary) as indicators. Covariance coverage was 1.000 for all indicators in both groups, indicating there were no missing values. The profiles were specified in a step-by-step procedure in which the number of profiles was increased by one each run, starting with a baseline one-profile model. Profiles containing more than 5 children (i.e., >5% of the sample) were considered large enough to interpret as a separate subgroup of children (Nylund-Gibson & Choi, 2018). The fit of the models was further evaluated using—in order of priority—a significant BLRT, low AIC, low sample-size adjusted BIC, and entropy value close to 1.00 (Geiser, 2013). The substantive interpretability of the separate profiles was also considered.

Within each profile, the pre-reading outcomes were compared to those found in the group of prospective adequate decoders, who performed similarly to the 973 children in the original data set (see Schaars et al., 2017c) and were thus seen as representative for typically developing children with adequate decoding skills.

3 | RESULTS

Descriptive statistics for all variables under study are presented in Table 2. Independent *t*-tests showed that the prospective poor decoders obtained significantly lower scores than the prospective adequate decoders on all measures, except for visual STM and vocabulary. To account for violations in the data regarding normality, linearity, and homoscedasticity, Kendall's tau-b was used to measure the associations among the pre-reading measures and between the word decoding and pre-reading measures (see Table 3).

In general, most correlations were stronger in the group of prospective adequate decoders than in the group of prospective poor decoders (see Table 3). This was likely related to the small variability in the word decoding and pre-reading outcomes in the group of prospective poor decoders (see e.g., Goodwin & Leech, 2006). The moderate to strong correlations among the word decoding measures in both groups confirmed that these tasks all measured the same theoretical construct. No correlations nearing 1.00 were found, so multicollinearity was not a problem (Allen et al., 2014). Moderate to strong positive correlations between the first phoneme isolation and word segmentation

TABLE 2 Pre-reading and word decoding measures for prospective poor and adequate decoders.

Pre-reading measure	Prospective poor decoders ($n = 90$) M (SD)	Prospective adequate decoders ($n = 90$) M (SD)	Independent samples t-test
First phoneme isolation	7.29 (2.57)	8.42 (1.89)	$t(163.44) = -3.37^{***}$ $d = 0.51$
Word segmentation	3.56 (2.26)	4.73 (2.59)	$t(178) = -3.25^{***}$ $d = 0.48$
Grapheme-to-phoneme knowledge	13.87 (6.88)	17.86 (7.53)	$t(178) = -3.71^{***}$ $d = 0.55$
RAN	34.07 (7.99)	39.39 (8.46)	$t(178) = -4.34^{***}$ $d = 0.65$
Verbal STM	13.82 (3.53)	14.88 (3.19)	$t(178) = -2.11^{*}$ $d = 0.32$
Visual STM	7.46 (3.04)	7.81 (3.16)	$t(178) = -0.77$ $d = 0.11$
Vocabulary	13.21 (4.50)	14.12 (4.42)	$t(178) = -1.37$ $d = 0.20$
WD_1	24.81 (7.43)	46.68 (24.08)	$t(105.80) = -8.23^{***}$ $d = 1.39$
WD_2	46.46 (16.44)	96.74 (44.30)	$t(113.06) = -10.10^{***}$ $d = 1.66$
WD_3	68.86 (14.43)	149.46 (50.22)	$t(103.59) = -14.63^{***}$ $d = 2.49$

Note: *t*-tests are all two-tailed.
Abbreviations: RAN, rapid automatized naming; STM, short-term memory; WD, word decoding timepoint.
$^{*}p < 0.05$; $^{**}p < 0.01$; $^{***}p \leq 0.001$.

TABLE 3 Nonparametric correlations between pre-reading and word decoding measures.

Measure	First phoneme isolation	Word segmentation	Grapheme-to-phoneme knowledge	RAN	Verbal STM	Visual STM	Vocabulary	WD_1	WD_2	WD_3
First phoneme isolation	-	0.52***	0.37***	0.13	0.31***	−0.01	0.11	0.02	0.06	−0.01
Word segmentation	0.41***	-	0.37***	0.19*	0.18*	0.10	0.14	0.06	0.10	0.04
Grapheme-to-phoneme knowledge	0.39***	0.46***	-	0.20**	0.05	0.18*	−0.06	0.07	0.10	0.08
RAN	−0.01	−0.06	−0.01	-	0.04	0.00	0.09	0.07	0.06	0.05
Verbal STM	0.28***	0.20*	0.08	0.10	-	−0.01	0.20**	0.00	−0.01	−0.13
Visual STM	0.22**	0.20*	0.21**	0.22**	0.03	-	0.05	0.11	0.00	0.03
Vocabulary	0.17*	0.10	0.04	0.23**	0.27***	−0.06	-	0.02	−0.08	−0.03
WD_1	0.22**	0.33***	0.26***	0.20**	0.11	0.13	0.01	-	0.38***	0.32***
WD_2	0.16*	0.29***	0.22**	0.17*	0.12	0.16*	0.04	0.59***	-	0.48***
WD_3	0.12	0.25***	0.16*	0.19**	0.16*	0.08	−0.02	0.52***	0.64***	-

Note: Correlations in the sample of prospective poor decoders are displayed above the diagonal, correlations in the matched group of prospective adequate decoders are displayed below the diagonal.

Abbreviations: RAN, rapid automatized naming; STM, short-term memory; WD, word decoding timepoint.

*$p < 0.05$; **$p \le 0.01$; ***$p \le 0.001$.

tasks in both groups confirmed that they both measured PA. In addition, moderate correlations between the two PA measures and the grapheme-to-phoneme knowledge task in both groups confirmed that these measured related constructs.

3.1 | Research question 1: Development of word decoding

3.1.1 | Development at the group level

The factorial mixed model ANOVA revealed significant main effects for time (F[1.86, 331.57] = 716.07, p < 0.001, $\eta_p^2 = 0.80$) and group (F[1, 178] = 147.44, p < 0.001, $\eta_p^2 = 0.45$) in addition to a significant interaction between group and time (F[1.86, 331.57] = 126.84, p < 0.001, $\eta_p^2 = 0.42$). Overall, this indicates that although both prospective poor and adequate decoders' word decoding skills improved over time, those of the prospective adequate decoders improved more (see Figure 1).

3.1.2 | Development at the individual level

Prospective poor decoders

All model fit indices except for the RMSEA indicated that the path model fitted the data well, $\chi^2(1) = 1.91$, $p = 0.17$; RMSEA = 0.10; CFI = 0.99; TLI = 0.96; SRMR = 0.04. The standardised path coefficients are displayed in Figure 2a.

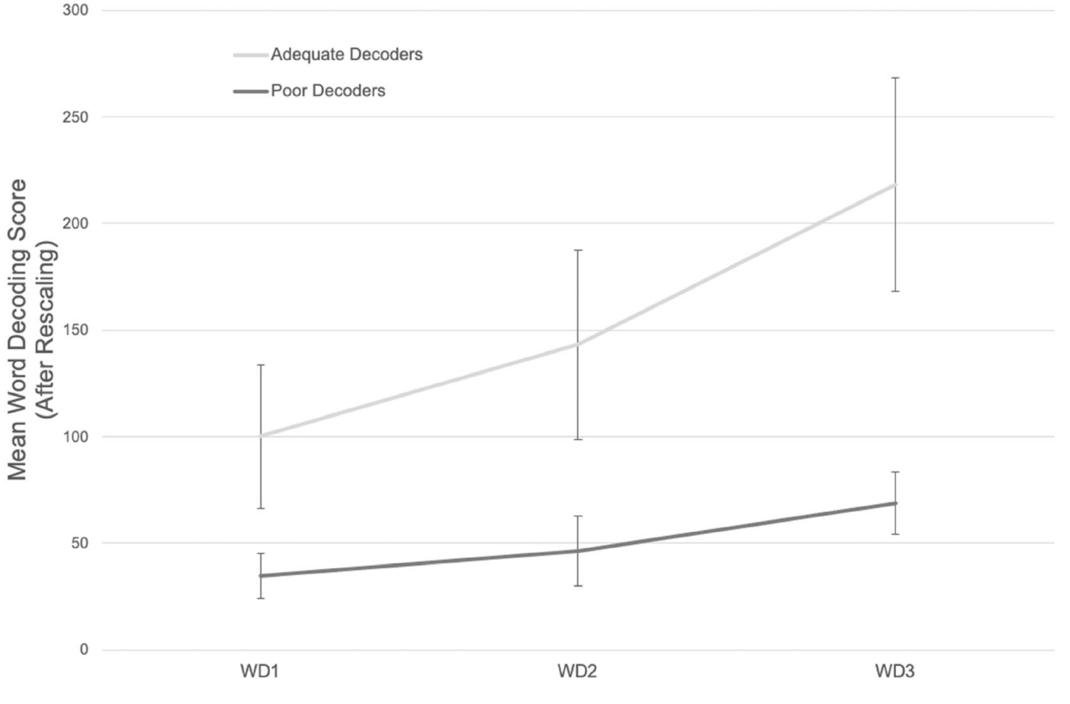

FIGURE 1 Word decoding development at the group level for prospective poor and adequate decoders. Error bars represent SDs. WD, word decoding timepoint.

Poor decoders' word decoding scores at WD_1 predicted their word decoding scores at WD_2 ($R^2 = 0.36$), which in turn predicted their scores at WD_3 ($R^2 = 0.33$). The indirect path from WD_1 to WD_3 also showed a significant, positive relationship with a standardised coefficient of 0.34 ($p < 0.001$).

Prospective adequate decoders

All model fit indices except for the Chi-square test and RMSEA indicated that the path model fitted the data well, $\chi^2(1) = 7.18$, $p = < 0.01$; RMSEA = 0.27; CFI = 0.97; TLI = 0.92; SRMR = 0.03 (see Figure 2b for standardised path coefficients). Prospective adequate decoders' word decoding scores at WD_1 predicted their word decoding scores at WD_2 ($R^2 = 0.66$), which in turn predicted their scores at WD_3 ($R^2 = 0.79$). The indirect path from WD_1 to WD_3 had a standardised coefficient of 0.72 ($p < 0.001$), also indicating a significant predictive relationship.

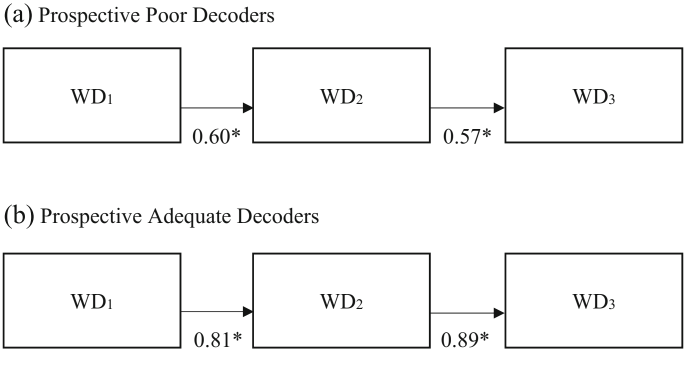

FIGURE 2 Word decoding development at the individual level for prospective (a) poor and (b) adequate decoders. The values below the arrows represent standardised coefficients. WD, word decoding timepoint. *$p < 0.001$.

TABLE 4 Model fit indices of latent profile analysis for prospective poor decoders.

Model	AIC	SS adj. BIC	Entropy	BLRT	Children per profile
1 profile	3544.50	3535.31	N/A	N/A	$n = 90$ (100%)
2 profiles	3467.47	3453.03	0.95	$p < 0.001$	1: $n = 15$ (17%) 2: $n = 75$ (83%)
3 profiles	**3437.44**	**3417.75**	**0.84**	**$p < 0.001$**	**1: $n = 14$ (16%)** **2: $n = 33$ (37%)** **3: $n = 43$ (48%)**
4 profiles	3422.75	3397.81	0.88	$p < 0.001$	1: $n = 3$ (3%) 2: $n = 32$ (36%) 3: $n = 13$ (14%) 4: $n = 42$ (47%)
5 profiles	3418.61	3388.43	0.91	$p = 0.24$	1: $n = 13$ (14%) 2: $n = 21$ (23%) 3: $n = 11$ (12%) 4: $n = 41$ (46%) 5: $n = 4$ (4%)

Note: The best fitting model is indicated in bold.
Abbreviations: AIC, Akaike information criterion; BLRT, bootstrapped likelihood ratio test; SS adj. BIC, sample-size adjusted Bayesian information criterion.

TABLE 5 Means and standard deviations of pre-reading measures per profile.

Pre-reading measure	Profile 1: Poor PA, letter knowledge, RAN, and verbal STM ($n = 14$) *M* (SD)	Profile 2: Poor PA and letter knowledge ($n = 33$) *M* (SD)	Profile 3: Poor RAN ($n = 43$) *M* (SD)
First phoneme isolation	2.18 (1.14)	7.33 (1.14)	8.90 (1.14)
Word segmentation	1.05 (1.60)	2.58 (1.60)	5.11 (1.60)
Grapheme-to-phoneme knowledge	9.54 (5.03)	9.39 (5.03)	18.72 (5.03)
RAN	31.79 (7.82)	35.75 (7.82)	33.50 (7.82)
Verbal STM	10.41 (3.17)	14.03 (3.17)	14.76 (3.17)
Visual STM	7.53 (2.95)	6.66 (2.95)	8.05 (2.95)
Vocabulary	11.58 (4.41)	13.81 (4.41)	13.27 (4.41)

Abbreviations: PA, phonological awareness; RAN, rapid automatized naming; STM, short-term memory.

3.2 | Research question 2: Pre-reading profiles

Based on the significant BLRT, low AIC and BIC values, and Entropy value close to 1.00, a model with four profiles of prospective poor decoders fitted the data best (see Table 4). However, one of the profiles contained only three children, so a model with three interpretable profiles was considered best (Nylund-Gibson & Choi, 2018).

A preliminary check revealed no differences between the profiles regarding gender, age, home language or non-verbal intelligence. A Kruskal-Wallis one-way ANOVA revealed that there were significant, medium-to-large differences in SES between Profiles 1 ($M = 2.67$, SD $= 1.12$, mean rank $= 31.72$), 2 ($M = 2.79$, SD $= 0.82$, mean rank $= 31.88$), and 3 ($M = 3.33$, SD $= 0.70$, mean rank $= 45.97$), H(corrected for ties) $= 9.07$, df $= 2$, $N = 77$, $p = 0.011$, $\eta^2 = 0.12$. Pairwise comparisons showed a significantly higher SES in Profile 3 (mean rank $= 39.90$, $n = 39$) than in Profile 2 (mean rank $= 27.24$, $n = 29$), $U = 355.00$, $z = -2.85$ (corrected for ties), $p = 0.004$, $r = 0.35$. There was also an apparent difference in SES between Profiles 1 (mean rank $= 17.67$, $n = 9$) and 3 (mean rank $= 26.08$, $n = 39$), but it did not reach statistical significance ($U = 114.00$, $z = -1.79$ [corrected for ties], $p = 0.074$).

Profile 1, 'Poor PA, Letter Knowledge, RAN, and Verbal STM', was the smallest profile (see Table 5) and was characterised by relatively poor scores on first phoneme isolation, word segmentation, grapheme-to-phoneme knowledge, RAN, and verbal STM, as compared to the group of prospective adequate decoders (see Table 2). Profile 2, 'Poor PA and Letter Knowledge', was characterised by lower scores on first phoneme isolation, word segmentation and grapheme-to-phoneme knowledge (see Tables 2 and 5) than the prospective adequate decoders. Profile 3, 'Poor RAN', was the largest profile and was characterised by relatively poor scores for RAN (see Tables 2 and 5).

Finally, we checked if the three groups of children displayed similar developmental trajectories of word decoding with a factorial mixed model ANOVA. The children in Profile 1 obtained lower word decoding efficiency scores than those in Profiles 2 and 3 at all three timepoints, but there were no significant differences between the groups.

4 | DISCUSSION

In the present study, we adopted a retrospective approach to investigate the early developmental pathways of prospective poor decoders as compared to matched prospective adequate decoders. In addition, we applied a bottom-up procedure to distil profiles of pre-reading skills and explore the heterogeneity in kindergarten within the group of later poor decoders.

4.1 | Research question 1: Development of early word decoding skills

Our results regarding development at the group level indicated that prospective poor and adequate decoders learning to read in Dutch acquired increasingly efficient word decoding skills as they progressed throughout early formal reading education. After half a year of formal reading instruction, a gap was visible between the two groups, which widened over time. This points towards a Matthew effect in early word decoding development. Although this widening pattern cannot be used to draw conclusions about reading development in the longer term (Pfost et al., 2014), these results show that decoding difficulties are already exposed during the critical first year of formal reading instruction. These results from actual prospective poor decoders strengthen findings from prediction studies with children at familial risk for later poor decoding skills (e.g., van Bergen et al., 2011). Regarding development at the individual level, the word decoding performance of both groups was autoregressive in nature over the first 1½ years of formal reading education.

Compared to other studies about the development of word decoding efficiency (e.g., Georgiou et al., 2021) the correlations between our word decoding timepoints were lower. This might be interpreted as lower stability in this sample, but it might also arise from limited variability in word decoding scores among the specific sample of poor decoders (Goodwin & Leech, 2006).

Our findings uphold our hypotheses and extend the results of previous studies on general word decoding development (e.g., Compton, 2000; Landerl & Wimmer, 2008; Schaars et al., 2017a, 2017c) to a specific group of children who struggle with learning to read in an intermediately transparent language like Dutch. In addition, they contribute to our knowledge about word decoding development and difficulties in the earliest stages of learning to read, before diagnosis of reading disorders.

4.2 | Research question 2: Profiles of pre-reading skills

Before the start of formal reading education, the group of prospective poor decoders had poorer PA, grapheme-to-phoneme knowledge, RAN, and verbal STM than matched prospective adequate decoders. This is in line with previous studies that found a relationship between these pre-reading skills and later word decoding abilities (e.g., de Jong & van der Leij, 2003; Landerl et al., 2013; Landerl & Wimmer, 2008). Visual STM and vocabulary did not differ between the two groups, corroborating prior research that did not associate these skills with word decoding abilities (e.g., de Jong & van der Leij, 2003; Kibby, 2009a; Landerl et al., 2013).

Using these pre-reading skills, we identified three different profiles within the group of prospective poor decoders: (1) Poor PA, Letter Knowledge, RAN, and Verbal STM; (2) Poor PA and Letter Knowledge; and (3) Poor RAN. This confirms our hypothesis that, in the population of kindergarten children with prospective word decoding difficulties in Dutch, various subgroups can be identified, based on compositions of pre-reading skills.

Profile 1 was characterised by poor PA, grapheme-to-phoneme knowledge, RAN, and verbal STM. This profile is in line with our hypothesis and many previous studies stating that poor decoders read both inaccurately and slowly due to multiple impaired pre-reading skills (e.g., de Jong & van der Leij, 2003; Wimmer et al., 2000). Furthermore, we correctly expected at least one profile to additionally include low memory skills. Deficient verbal STM may exacerbate poor PA (Kibby, 2009b; Preßler et al., 2014), and thus hamper children in their word decoding efficiency (Knoop-van Campen et al., 2018). Vice versa, poor PA skills may be compensated by better verbal STM, as these pre-reading skills did not appear together in other profiles. Together, these skills contribute to the identification of homogeneous subgroups in a sample of prospective poor decoders.

Profile 2 was characterised by poor performance on the PA tasks and poor grapheme-to-phoneme knowledge. We had not expected a profile with solely poor PA skills, and this is indeed confirmed since grapheme-to-phoneme knowledge is included in the profile. This finding is in line with previous research in transparent orthographies and agrees with the conclusion of the recent review study of Landerl et al. (2022) that PA skills are often intertwined with grapheme-to-phoneme knowledge, which together are associated with later reading skills.

Examination of the characteristics of Profile 3 revealed poor RAN skills. This confirms the single RAN deficit hypothesis in the context of Dutch (Wimmer et al., 2000). Furthermore, the children in Profile 3 had a higher SES than those in Profile 2. Ozernov-Palchik et al. (2017) also found a profile of poor decoders characterised by average performances on pre-reading measures, which contained predominantly children from medium to high SES backgrounds. They reason that parents with a higher SES may invest more in their children's early literacy development. It can be speculated that, through better access to resources and extra stimulation of pre-reading skills at home, these children perform better on the 'trainable' kindergarten measures—such as PA—as compared to their peers from lower SES families (see also Hood et al., 2008; Melhuish et al., 2008). Nevertheless, their underlying susceptibility might be exposed as soon as literacy tasks become more complex and demanding, like the word decoding tasks in Grades 1 and 2. This idea of sensitivity to increasing task demands was previously proposed by Van der Leij and Van Daal (1999) and Schaars et al. (2017b). The current findings, therefore, indicate that a high SES may be a protective factor regarding the acquisition of pre-reading skills but might be unable to compensate for sensitivity to the increasing demands of word decoding tasks during later reading development.

We did not find profiles with poor visual STM or vocabulary. This suggests that these pre-reading skills do not contribute to the identification of homogeneous subgroups of Dutch prospective poor decoders. As visual STM did not correlate with verbal STM, we can also presume these pre-reading skills to represent different aspects of STM (Alloway et al., 2006), only one of which is related to later word decoding abilities.

4.3 | Implications

From a fundamental perspective, our results provide more and better insight into the characteristics of this group of children in the stage of emergent literacy. We provide evidence for the current perspective that poor academic outcomes, including word decoding difficulties, manifest at the intersection of a multitude of risk factors and are not the result of a single deficit (e.g., Catts & Petscher, 2021; Ozernov-Palchik et al., 2017). In addition, we focused on the context of young children learning to read in Dutch, both narrowing the scope of previous findings to a specific population and broadening the generalisability of results from studies in other intermediately transparent orthographies. Lastly, we determined our sample at a later point in time, which allowed us to uniquely study development in retrospect. In this way, we were better able to explain what characterises this population of poor decoders than predictive studies.

From an applied perspective, the autoregression found at the individual level indicates that children with poor decoding skills in Grade 2 are likely to have been experiencing difficulties from the very beginning. Although the word decoding efficiency of prospective poor decoders improves slightly over time, that of prospective adequate decoders shows a stronger increase, indicating a widening achievement gap. This emphasises the need for specific attention already to children who perform poorly on early word decoding tests. These children are at risk for developmental delays and early additional support may prevent later, more severe problems.

Regarding the pre-reading profiles, kindergartners with poor PA, grapheme-to-phoneme knowledge, and/or RAN, along with other impaired pre-reading skills, are at risk for developing word decoding difficulties and should receive extra support during emergent literacy. The finding that the largest portion of prospective poor decoders came from high SES backgrounds also bears the implication that a supportive home literacy environment, which is associated with higher SES, does not prevent persistent and severe word decoding difficulties.

4.4 | Limitations

A limitation that needs to be considered, concerns the criterion distinguishing poor from adequate decoders. As stated above, the use of the 10th percentile as a clinical threshold is a matter of continuing debate (e.g., Ozernov-

Palchik et al., 2017; Protopapas, 2019). It is often seen as an arbitrary cut-off point that leads to a categorical division of children on a continuum of word decoding abilities. Children with slightly better word decoding skills were marked as adequate decoders, although they may also benefit from intervention targeted at improving word decoding skills.

A second limitation pertains to the short and early time frame in which we studied the consistency of word decoding development. As such, we cannot draw any conclusions about the development of word decoding skills over a longer period. Future research could extend our findings by studying the development of word decoding skills throughout the higher grades of primary school.

In addition, we were not able to distinguish word decoding accuracy from word decoding speed, as the schools provided us with composite efficiency data (i.e., number of words read correctly per minute). This hinders direct comparison with studies that separated decoding accuracy from speed (e.g., Compton, 2000; Parrila et al., 2005).

5 | CONCLUSIONS

In conclusion, we found that over the course of the first 1½ years of formal reading education, the word decoding skills of poor decoders improve, but the distance to their adequately reading peers increases. It would be interesting to continue this line of research to discover more about longer-term word decoding development and to be able to make outcome predictions. When retrospectively studying the characteristics of these children in kindergarten, we found heterogeneity in their pre-reading skills, allowing us to group them in homogeneous subgroups. This study provides one step towards the goal of enabling more targeted support by characterising the variations in developmental profiles in the first 1½ years of learning to read.

CONFLICT OF INTEREST STATEMENT

The authors declare that they have no conflict of interest.

DATA AVAILABILITY STATEMENT

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

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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