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Exploring the double deficit hypothesis in Spanish schoolchildren using latent profile analysis

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Abstract: **Background:** Dyslexia is a neurodevelopmental disorder caused by deficits in phonological awareness (PA). According to the Double Deficit Hypothesis (DDH), Rapid Automatic Naming (RAN) deficit is another potential independent cause. However, the evidence from studies with languages that vary in orthographic consistency is mixed.

Methods: The present study aims to investigate the heterogeneity of profiles based on PA and RAN in a sample of Spanish kindergarten children -a consistent orthography- before they start reading instruction (Time 1) to see whether these profiles could predict reading difficulties 2 years later (Grade 2, Time 2). At T1, 795 children were assessed on PA, RAN, letter knowledge (LK), and Verbal Short-term memory (VSTM). At T2, 373 children were reassessed on reading measures. To avoid arbitrary cut-points, profiles were established through Latent Profile Analysis (LPA).

Results: Four profiles emerged at both T1 and T2. No single PA or RAN profiles were found. Only the group of low performers corresponded to the Double Deficit profile. The T1 Low-performance group exhibited higher stability than the other groups: 92.5% of the low performers in kindergarten demonstrated poor reading ability in Grade 2, supporting the DDH prediction that children with deficits in both PA and RAN would be more severely impaired than the rest of the profiles. LK showed a relevant contribution in predicting impairment severity.

Conclusions: Partial evidence supporting the DDH was obtained. The LPA proved to be appropriate for risk identification under a dimensional conceptualization.

Keywords: Double Deficit Hypothesis (DDH), Latent Profile Analysis (LPA), Phonological Awareness (PA), prediction reading difficulties, Rapid Automatic Naming (RAN)

Highlights

What is already known about this topic

- DDH assumes that RAN and Phonological skills are separable predictors of reading deficits.
- Three deficit profiles are expected: Phonological, Speed Naming, and a combination of both deficits (Double Deficit).

What this paper adds

- The role of DDH to predict reading difficulties is examined for the first time in a large Spanish sample, a consistent orthography.
- A combination of both skills, rather than RAN or PA separately, explains the deficit profiles.
- DDH plays a less relevant role in predicting reading difficulties in consistent orthographies.

Implications for theory, policy or practice

- LPA proved suitable to capture the dimensional nature of reading difficulties.
- Profiles based on performance relative to the sample are stable and reliable tools for screening reading difficulties.
- Short tasks administered by school personnel can detect children at risk of reading difficulties.

Dyslexia is a neurodevelopmental learning disability characterized by difficulties acquiring fluent and accurate word reading and spelling (Snowling et al., 2020). It is one of the most common learning disorders with estimated prevalence of 5% to 12% (Carrillo et al., 2011; Jiménez et al., 2009; Moll, Kunze, et al., 2014). The dominant view is that deficits affecting the processing of speech sounds are the underlying cause of reading impairment (Vellutino et al., 2004). The Double Deficit Hypothesis (DDH) suggests that deficits in Rapid Naming represent another potential cause of reading difficulties. Thus, children might show different reading profiles according to the component affected (Bowers & Wolf, 1993; Wolf & Bowers, 1999). However, studies exploring the predictions made by the DDH reported inconsistent findings, particularly when orthographic consistency is considered. This study examines whether profiles of reading can be identified in a large sample of Spanish kindergarteners under the frame of the DDH using Latent Profile Analysis (LPA), and whether these profiles predict early literacy development.

Several studies highlight that phonological awareness (PA), particularly the awareness of phonemes -the ability to perceive and consciously manipulate individual sounds in spoken words- is a strong predictor of reading progress (Goswami, 2002). Supporting this view, high sensitivity to speech segments is associated to success in learning to read (Defior, 2008; Melby-Lervag et al., 2012), while deficits in PA are linked to reading difficulties (Hulme & Snowling, 2015). Furthermore, reading outcomes were improved when children were trained on PA (Hulme et al., 2012; Torgesen et al., 2010). Another predictor of how well children will progress in learning to read is the ability to quickly name a series of familiar items, known as Rapid Automatic Naming (RAN). Children with low efficiency in RAN are likely to show slow progress in reading and to experience reading difficulties (Caravolas et al., 2012; Puolakanaho et al., 2007; Ziegler & Goswami, 2005).

An important proposal is that RAN and PA skills cover different underlying mechanisms of reading (de Jong & van der Leij, 2002; Norton & Wolf, 2012; Powell et al., 2007). While PA only operates with verbal stimuli, RAN also requires the recall of lexical items stored in long-term memory through the identification of familial visual stimuli (Araujo et al., 2015). Thus, beyond phonological coding skills, RAN may imply processes that integrate visual and linguistic information, and processes underlying word retrieval (Georgiou et al., 2016). This led Wolf and Bowers (Bowers & Newby-Clark, 2002; Wolf & Bowers, 1999) to argue that RAN taps into other non-phonological processes relevant for building orthographic representations (Bowers & Newby-Clark, 2002; Georgiou et al., 2008) and processes mediating whole-word processing (Araujo et al., 2011) that PA may not capture.

As evidence that PA and RAN skills contribute to specific domains of literacy processing, first, only moderate correlations between PA and RAN have been found (Swanson et al., 2003; Clarke et al., 2005). Second, some children with dyslexia have RAN difficulties in the absence of phonological difficulties (Kirby et al., 2003; Powell et al., 2007; Wolf & Bowers, 1999). Third, PA and RAN show different developmental trends according to literacy skills, orthographic consistency, and reading component, i.e., fluency vs accuracy (Georgiou et al., 2012; Powell & Atkinson, 2021). Longitudinal studies showed that RAN is related to fluency in both consistent and inconsistent orthographies (Georgiou et al., 2008; Moll, Ramus, et al., 2014), whereas PA is preferably associated with reading accuracy (Georgiou et al., 2008; Kirby et al., 2010). Landerl et al. (2019) revealed that RAN was the best predictor of fluency across orthographies, but the PA reading relationship varied with age and orthographic consistency. Again, Powell and Atkinson (2021) confirmed the RAN relation to the accuracy and fluency of word reading, while the prediction of PA was limited to accuracy in children learning to read in English. Regarding Spanish samples, Suárez-Coalla et al. (2013) reported that pre-readers' PA skills predicted word reading accuracy, while RAN predicted fluency. Similarly, Rodríguez et al. (2015) found that the PA skills shown by 6 to12-year-old children correlated with the accuracy, but not the speed, of word and pseudoword reading. RAN was associated with fluency and word accuracy in all reading tasks, except pseudoword accuracy. Arguably, PA and RAN skills reflect different reading resources. The first is linked to sequential one-to-one decoding based on grapheme-to-phoneme correspondence rules. In contrast, RAN involves retrieving phonological representations from visual stimuli, a process that partially parallels the access to phonological representations from words that occurs as orthographic processing develops (Landerl & Wimmer, 2008; Norton & Wolf, 2012; Onochie-Quintanilla et al., 2019). This would explain that RAN accounts for a higher amount of variance for exceptional-word than for nonword reading, or that it is strongly related to fluency in both consistent and inconsistent orthographies. In turn, PA linked to serial grapheme-to-phoneme processing plays a lesser role as reading mechanisms progressively evolve to the processing of multiple letters at a time (Lervag & Hulme, 2009; Protopapas et al., 2013). However, the influence of RAN persists during later reading development when reading success relies on the processing of frequent letter patterns or whole words as units (de Jong, 2011; Kirby et al., 2003).

Consistent with the claim that PA and RAN mean independent sources of reading achievement and failure, Wolf and Bowers (Norton & Wolf, 2012; Wolf & Bowers, 1999) proposed that either PA or RAN deficits would be sufficient to place an individual at risk of reading difficulties. Accordingly, children might show three different profiles of reading impairment: (1) PA deficit (PAD) with difficulties in decoding and word reading, but good naming speed; (2) RAN deficit (RAND) with slow naming and low fluency, but without phonological difficulties; and (3) a combined subtype (Double Deficit; DD) with both skills affected, expected to show the most severe difficulties.

The findings concerning the DDH profiles are mixed. Studies in consistent and inconsistent orthographies demonstrated that children classified according to their performance on RAN and PA differ in their reading progress and in the severity of their difficulties. Powell et al. (2007) confirmed that in a sample of 7- to 10-year-old British children, a group showed deficits only in RAN or only in PA, and a smaller group showed DD. Compton et al. (2001) found a RAND group that outperformed a PAD group in non-word reading but was more impaired on word-identification measures (accuracy and rate). On the contrary, the PAD subgroup tended to be more impaired in accurate non-word-identification. Similarly, Kirby et al. (2003) tracked 161 Greek children for 6 years who were classified as DDH in kindergarten. Although the three impaired profiles remained worse readers than controls, the PAD group reduced their deficit overtime, while the RAND and DD groups performed poorly on reading throughout the study. Papadopoulus et al. (2009) followed 242 Greek children from kindergarten to second grade observing that deficits were persistent and group differences increased with age. The RAND group was particularly impaired on word and text speed measures.

Other studies found little support for a single naming deficit subtype. Pennington et al. (2001) observed that only one participant among 71 children aged 7 to 18 years with dyslexia showed naming deficits in the absence of phonological processing difficulties. Similarly, Vaessen et al. (2009) found that 90% of Dutch children with dyslexia aged 6 to 13 years with naming speed problems also showed phonological deficits. In Spanish, single deficits were also less frequent than the DD profile in a typically developing population of 7-to-12-year participants (Jiménez et al., 2008), and in a group of 8 to 13 years average and poor readers (López-Escribano, 2007). Nonetheless, DD children consistently made the slowest progress in reading and exhibited the most severe deficits.

Discrepancies in profile distribution have been attributed to participants' reading proficiency or orthographic consistency (Seymour et al., 2003). In consistent orthographies, words can be successfully recognized based on grapheme-to-phoneme correspondences. Because consistent correspondences are easy to learn, decoding abilities develop rapidly, so subsequent differences in accuracy of decoding are difficult to detect. In turn, the letter-sound regularity facilitates children's awareness of the phonological structure of words (Nation & Hulme, 2011). Thus, the contribution of the PA skills involved in decoding to predict differences in reading proficiency may be exacerbated at the first stages of reading (Kirby et al., 2003; Landerl et al., 2019; Nation & Hulme, 2011). However, the RAN effects turn more observable at later phases, when fluency becomes a more reliable measure of reading proficiency than accuracy (de Jong & van der Leij, 1999). In contrast, decoding does not suffice the demands of inconsistent orthographies characterized by complex grapheme-to-phoneme relationships. Thus, from the onset of literacy, reading competency relies also on the ability to process letter clusters. Consequently, in inconsistent orthographies, RAN may take a value in defining profiles in beginning readers that may not be generalizable to consistent orthographies (Landerl et al., 2013, 2019; Moll, Ramus, et al., 2014). These time-based changes in the relationship between phonological and naming abilities and reading achievement suggest that, at the onset of literacy, single profiles may be appropriate for describing deficits in inconsistent orthographies but be inaccurate in consistent orthographies. Therefore, studying children's profiles before they start reading instruction in consistent orthographies could shed light on the accuracy of the DDH.

Subtype classification of reading skills

Also critical is the application of arbitrary criteria to establish discrete boundaries between subtypes (e.g., below some percentile on a test). The assumption that reading skills lie on a continuous dimension (Hulme & Snowling, 2015; Shaywitz et al., 2008) suggests that cut-offs are unlikely to represent a true boundary. The selection of a more or less conservative criterion may affect the proportion of children who are assigned into at-risk groups (Snowling et al., 2020). To avoid arbitrary cut-points, Latent Profile Analysis (LPA) has been recently incorporated to investigate the heterogeneity of profiles. LPA classifies individuals with varying degrees of probability into distinct groups (profiles) with different configural attributes. The most relevant advantage of LPA is that, instead of applying arbitrary criteria, individuals are grouped by the probability of their response patterns on each of the latent profile indicators. Participants are classified into profiles based upon membership probabilities estimated directly from the data distribution (or model) instead of searching for similarities between cases. The model-fitting process begins with a one-profile model (i.e., all readers are hypothesized to demonstrate a single, homogeneous profile) to which additional profiles are added one at a time. Statistical tests are conducted at each step to determine if the additional profile significantly improves the goodness of fit of the model. Thus, LPA is appropriate for risk identification under a dimensional conceptualization that places children on a continuum of abilities and disabilities.

Two recent studies applied LPA to examine the DDH in pre-readers with discrepant results. Ozernov-Palchik et al. (2017) assessed 1215 English-speaking pre-kindergarten and kindergarten children (mean age 5.5 years) in IQ, PA, RAN, Letter Knowledge (LK), Short-Term Visual Memory (VSTM) and Word reading. A subset of 90 children were re-tested at the end of Grade 1 (mean age 7.2 years) in several measures of reading (word and pseudoword reading, reading fluency and comprehension), spelling and processing speed. At time 1, apart from high (19%), average (31%), and low-average performers (21%), three profiles consistent with the DDH emerged: a RAND profile (11%) with average scores on all measures but RAN; a PAD profile (6%) with the lowest PA scores but higher RAN than the other risk profiles; and a DD profile (12%) with low RAN and PA scores. The contrast between PAD and RAND profiles was taken to support the independence of the RAN construct in the occurrence of reading deficits, and to suggest that PA deficits may not be sufficient to produce reading difficulties, despite the low PA scores shown by the low-average, PAD, and DD profiles. Furthermore, both profiles evolved in line with the expected pattern. The PAD group showed their worst results in tasks with high demands on decoding. Conversely, the RAND group obtained their lowest scores in word reading, fluency, and RAN.

Less favourable for the DDH were the four profiles based on nonverbal IQ, PA, LK, RAN, and parental-environmental measures reported by Verwimp et al. (2020) in a sample of 1091 Dutch-speaking kindergartens, a consistent orthography: high (17%), average (40%), below average with average IQ (26%), and below average with below average IQ performers (18%). Although the two risk profiles significantly differed in IQ and RAN scores, no pure PA or RAN deficits were found.

Considering the relevant role of profiles in predicting reading development, the stability of profile membership represents another relevant issue. Stability is key to detecting children at risk of reading failure (Fuchs & Fuchs, 2017). Reading profiles demonstrated fairly stable: for example, over 50% in Furnes et al. (2019) and Spector (2005), higher than 70% in Steacey et al. (2014) or Torppa et al. (2012), figures that are far from the 100% stability reported by Ozernov-Palchik et al. (2017). Most research showed that profile membership fluctuates over the course of reading instruction (Hulme et al., 2012) and that stability differs across subgroups. Children without deficits and children with the lowest performance, who are less likely to overcome their difficulties, tend to remain in the same group (Furnes et al., 2019; Torppa et al., 2012). Furthermore, examining the skills involved in profile transitions can provide evidence to design focused interventions to prevent or reduce reading difficulties (Spector, 2005).

The present study

Evidence suggests that orthographic consistency likely affects the contribution of PA and RAN in distinguishing between good and poor readers. Using LPA, Ozernov-Palchik et al. (2017) showed that the profile distribution of children who learned to read in an inconsistent orthography was perfectly in line with the DDH. However, no single profiles were obtained in the case of Verwimp et al., whose participants learned a consistent orthography. Thus, to further investigate the generalizability of profiles based on PA and RAN across orthographies, the present study examined a sample of Spanish kindergarteners, a highly consistent orthography. Previous studies have shown that a single RAND profile was not frequent among Spanish children (López-Escribano, 2007), and that their performance was only slightly different from that of the PAD profile (Jiménez et al., 2008). However, the participants in the above-mentioned Spanish studies counted with at least 2 years of reading experience. Because of the transparency of grapheme-phoneme correspondences in Spanish, children might have received a great deal of explicit phonics instruction that likely has affected individual differences in the acquisition of reading and phonological abilities. Thus, beyond identifying early profiles, it is important to understand how children's difficulties evolve. However, Verwimp et al. did not present longitudinal data, and unfortunately, to our knowledge, there are no longitudinal studies examining the DDH among Spanish pre-readers. Therefore, in the current study, kindergartener's profiles were assessed to avoid the influence of literacy training in the predictor measures, and their performance was compared with that obtained at the end of Grade 2. Finally, we assessed whether early DDH profiles predicted later reading development and examined profile stability from kindergarten to Grade 2.

Three questions were addressed:

1. Do single profiles based on PA and RAN measures emerge before the start of reading instruction in Spanish, a consistent orthography?

2. How well do these profiles predict reading development in Spanish children?
3. How stable is subtype membership from kindergarten to Grade 2?

Based on previous research, we hypothesized a relevant role of PA in the distribution of profiles. However, a RAND profile was not expected. Children with PA and RAN deficits (DD group) would show the worst performance in kindergarten and reach the lowest scores on reading measures 2 years later. Finally, the DD subtype was expected to show the highest proportion of children remaining in that subtype across the two time points.

Methods

Participants

The current study was part of the Leeduca project aimed to identify children with learning disorders inspired on RTI models. Children were tested at two time-points, at Third Grade of kindergarten (T1; ~ 5 years) and 2 years later at Grade 2 (T2 ~ 7 years). At Time 1, the initial sample comprised 926 children attending 1 private, 32 public schools distributed all over the province. The sample covered the full range of socioeconomic status (SES) as supplied by the Education Department. The number of children in low, medium, and high SES was 195, 307, and 293 at T1; 100, 159, and 114 at T2. Sixty-seven children (8%) with the lowest 5% scores in non-verbal intelligence, 56 children (6%) with incomplete scores, and 8 children (1%) with unreliable scores were excluded from analysis. The final T1 sample comprised 795 participants (M = 69.88 months, SD = 3.64). At Time 2, 13 schools declined to participate reducing the sample to 410 children. Thirty-seven children (9%) with incomplete computed scores were excluded from analysis. The final T2 sample comprised 373 participants (M = 93.91 months, SD = 3.52).

This study was approved by the ethics committee of the University of Malaga (Reference: 16–2020-H) and was performed following the standards of the Declaration of Helsinki. Written parental consent for participation was obtained.

Tests and procedures

Children were individually assessed three times a year by speech-therapy teachers. A web-based platform was used for test administration and data collection. All stimuli were presented on the computer screen. Each session lasted 20–30 minutes. For a complete task description and time schedule, see Supplementary Material.

Time 1

Non-verbal intelligence (IQ). A, B and AB forms from the *Raven's Coloured Progressive Matrices* were used (CPM; Raven et al., 1994).

Phonological awareness (PA). The number of correct responses and time to complete the task were recorded. *Syllable counting*. Children counted the number of syllables in 20 words. α: 0.865. *Initial syllable matching*. Children selected from 6 arrays of three pictures the one whose name starts with the same syllable as the object depicted above. α: 0.629. *Initial syllable deletion*. Children said the name dropping the initial syllable.

Ten items. α: 0.915. *Initial/Final phoneme deletion*. Children said the name dropping the initial (10 items. α: 0.871) and final (8 items. α: 0.873) phoneme. *Initial phoneme isolation*. Children said the first sound of 20 names. α: 0.940. *Phoneme segmentation*. Children said the number of sounds in 10 monosyllabic and disyllabic words. α: 0.858.

Rapid Automatized Naming (RAN). Three rapid naming tasks comprising objects that children named as quickly as possible from left to right.

Letter knowledge (LK). Children said the name or the sound of the 26 letters of the Spanish alphabet presented in capital and lowercase one by one. Time limit 60 s. α: 0.973.

Verbal short-term memory (VSTM). Children repeated 3 sequences of 1, 2, 3, 4, and 5 CV and CVC syllables 30 items. α: 0.760.

Time 2

Word/Pseudoword reading (W). Children read aloud 6 lists of 12 two-, three-, and four-syllable words/pseudowords. Words α: 0.913, 0.921, and 0.864; Pseudowords α: 0.861, 0.818, and 0.734.

Complex syllable reading (CS). Children read aloud 18 CVC and CCV syllables. α: *0*.945.

Text reading fluency (FLU) and comprehension (COM). Children read twice two texts from *EDICOLE* (Gómez-Veiga et al., 2020). The first reading was used to assess reading speed. After the second reading, children answered 10 questions. α: 791 and 0.782.

Reading efficiency (RE). *TECLE* (Carrillo et al., 2024), a 5-minute test where children had to choose one word from four options to complete a sentence: 64 items. α: 0.946.

Orthographical decision (OD). Children selected from two options the correct spelling of 26 frequent words. α: 0.796.

Data preparation and analysis

Prior to analysis, measures from similar constructs were averaged and standardized in z-scores to obtain composite variables. The predictor PA consisted of syllable counting, initial syllable matching, initial syllable deletion, initial/final phoneme deletion, initial phoneme isolation, and phoneme segmentation. Word reading (W) included two-, three-, and four-syllable word reading. Pseudoword reading (PW) was composed of two-, three-, and four-syllable pseudoword reading. Reading fluency (FLU) and reading comprehension (COM) were calculated from text reading speeded tasks and text comprehension tasks, respectively.

To identify homogeneous profiles, LPA based on kindergarten measures of IQ, PA, RAN, VSTM and LK was conducted by means of *R* (R Core Team, 2020) using the packages *tidyLPA*, *dplyr* (Wickham et al., 2021), *MplusAutomatio*n (Hallquist & Wiley, 2018), and *Mclust* (Scrucca et al., 2016). If no values were specified, variances were constrained to be equal across profiles, and covariances fixed to zero. Model 1 preserved parsimony with the most constrained number of groups.

Attrition analyses only observed differences in Profile 1 (*High-Performance*) between children who stayed and those who left the study in the RAN [$F(1, 787) = 10.47$, $p = 0.001$], and LK [$F(1, 787) = 15.10$, $p < 0.001$] measures. No differences were found in IQ, PA, or VSTM, or in the other profiles (all ps > 0.18). We concluded that attrition did not pose a threat to the study.

The following criteria were used to determine the optimal number of profiles: (1) *Information criteria* (Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC), (2) *Bootstrapped likelihood ratio test* (BLRT). Statistical tests were conducted at each step to determine if the additional profile significantly improved the goodness of fit of the model. Specifically, AIC and BIC were used to avoid overfitting, adjusting the log likelihood value (LL) to account for the number of estimated parameters in the model with lower values indicating a better model fit to the data. Difference in LL value between models with k (H1) and k-1 (H0) profiles were used to estimate a bootstrapped value *p*. A significant value indicated a noteworthy improvement in model fit. The least restricted model was chosen for reasons of parsimony. (3) *Acceptable entropy values*. High entropy means that an individual has high probability of belonging to one profile and low probability of belonging to others. Values above 0.60 indicate acceptable classification. (4) *Profiles size*. Models with profiles comprising less than 8% of participants were not considered. In this study, 1–4 profile models fitted the data.

Once latent profiles were identified, follow-up univariate analyses of variance (ANOVA) were conducted with the IBM SPSS version 23.0 (IBM Corp., 2015) to check for differences among the profiles. Significant effects were investigated with pairwise post-hoc comparisons. For both LPA and follow-up analyses, the significance level was set at 0.01 to account for the highest number of false positives in large samples.

Results

Time 1

The goodness of fit statistics in the first evaluation is shown in the upper half of Table 1. The baseline model that estimated a 1-profile model was used to test whether subsequent models with additional profiles provided a significant improvement in model fit. The AIC value decreased from one to five profiles, whereas the BIC value decreased from one through to four profiles, indicating the 4-profile model as the best-fit candidate.

In this case, only AIC and BIC were considered to select the 4-profiles model because the BLRT was significant, the entropy value was acceptable, and the profile sizes were represented by a big enough percentage of children (higher than 9%).

Profiles description Time 1

As illustrated in Figure 1A, the four latent profiles were defined with a wide number of participants (see Table 2).

Profile 1

High performers ($N = 191$, 24.03%) showed high performance (between 0.4 and 1.2 SD above average) across all measures, particularly on PA and LK.

Table 1. Goodness of fit statistics for model comparisons in Time 1 and Time 2.

Model	AIC	BIC	Entropy	Prob min	Prob max	N min	N max	BLRT p
Time 1								
1 profile	11099.33	11146.12	1.00	1.00	1.00	1.00	1.00	
2 profiles	10545.71	10620.56	0.76	0.89	0.95	0.34	0.66	0.01
3 profiles	10383.31	10486.24	0.77	0.85	0.92	0.11	0.47	0.01
4 profiles	10326.68	*10457.68*	0.71	0.80	0.89	0.10	0.37	0.01
5 profiles	*10311.67*	10470.73	0.69	0.54	0.90	0.10	0.30	0.01
Time 2								
1 profile	7430.69	7485.59	1.00	1.00	1.00	1.00	1.00	
2 profiles	6410.74	6497.01	0.87	0.96	0.96	0.44	0.56	0.01
3 profiles	5856.45	5974.10	0.91	0.94	0.97	0.21	0.53	0.01
4 profiles	5539.70	5688.72	0.92	0.94	0.95	0.08	0.42	0.01
5 profiles	5360.85	5688.72	0.93	0.93	0.98	0.05	0.39	0.01
6 profiles	5161.01	5372.77	0.94	0.94	0.99	0.05	0.33	0.01
7 profiles	5040.65	5283.79	0.93	0.93	1.00	0.05	0.28	0.01
8 profiles	5006.24	*5280.75*	0.89	0.81	1.00	0.05	0.23	0.01
9 profiles	*4989.66*	*5295.54*	0.88	0.82	1.00	0.05	0.17	0.01

Note: Lowest AIC and BIC values in italics.
Abbreviations: AIC = Akaike information criterion; BIC = Bayesian information criterion; BLRT = Bootstrapped likelihood ratio test; N max = percentage of individuals in the largest profile of the model; N min = percentage of individuals in the smallest profile of the model; Prob max = probability of the classification accuracy of the largest profile in the model; Prob min = probability of the classification accuracy of the smallest profile in the model.

Profile 2

Above-average performers (N = 291, 36.60%) obtained above average scores on all measures, particularly on PA that exceeded the mean 0.4 SD.

Profile 3

Below-average performers (N = 237, 29.81%) scored below average on all measures, particularly on PA and LK, with scores 0.4 SD under the mean.

Profile 4

Low performers (N = 76, 9.56%), considered the high-risk profile, showed low RAN, VSTM, and LK (between 0.7 and 1.3 SD below average) and very low PA (2 SD below average).

The upper half of Table 3 demonstrates a relationship between the classification of profiles and each variable (IQ, PA, RAN, VSTM and LK) based on significant differences between profiles. This analysis was confirmed by *post hoc t*-tests using the Bonferroni correction. Significant differences were found for all pairwise comparisons in IQ (all ps <0.004); PA (all ps <0.001); RAN (all ps <0.001); VSTM (all ps <0.001), except above and below-average performers (p = 1.000); and in LK (all ps <0.001).

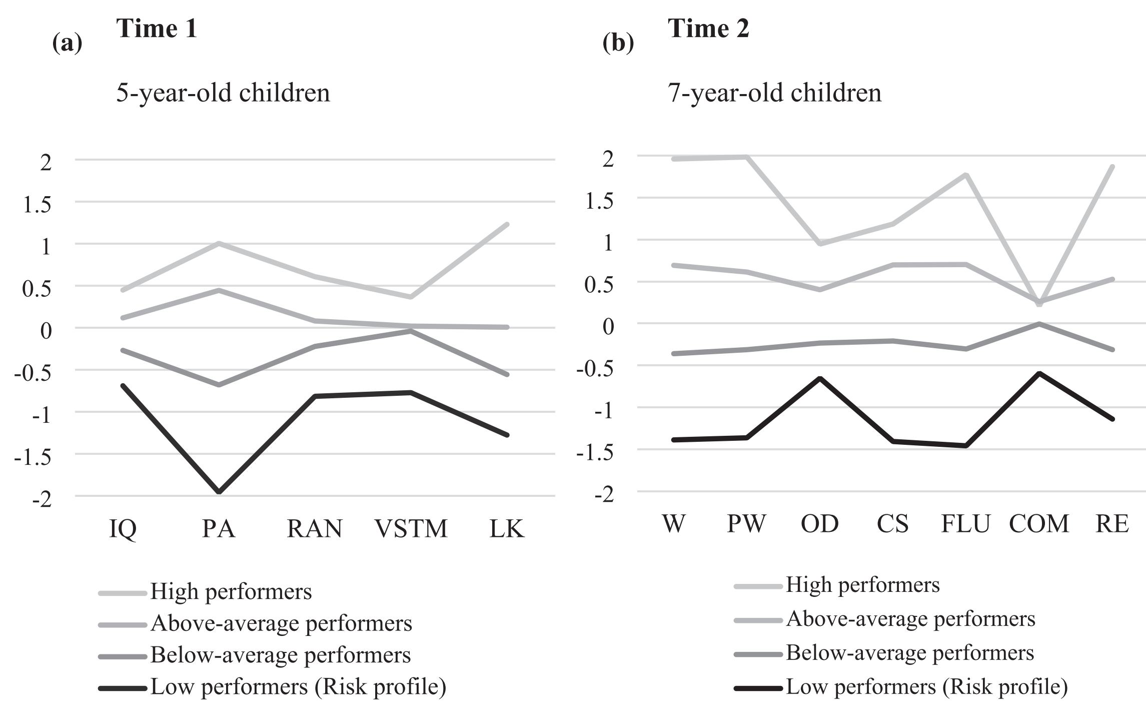

Figure 1. Profile plot for the 4-profiles models in Time 1 (A) and in Time 2 (B). *Note*: Direct scores were rescaled in z scores. COM = Reading Comprehension; CS = Complex Syllable reading; FLU = Reading Fluency; IQ = Intelligence Quotient; LK = Letter Knowledge; OD = Orthographic Decision; PA = Phonological Awareness; PW = Pseudoword Reading; RAN = Rapid Automatized Naming; RE = Reading Efficiency; VSTM = Verbal Short-Term Memory; W = Word reading.

Table 2. Number and percentage of children according to the profile models in Time 1 and Time 2.

	8-profile model		7-profile model		6-profile model		5-profile model		4-profile model	
Time 1	*N*	%	*N*	%	*N*	%	*N*	%	*N*	%
Profile 1							188	23.648	191	24.025 (High)
Profile 2							207	26.038	291	36.604 (Above)
Profile 3							237	29.811	237	29.811 (Below)
Profile 4							86	10.818	76	9.569 (Low)
Profile 5							77	9.686		
Time 2										
Profile 1	45	12.064	17	4.558	23	6.166	30	8.043	30	8.043 (High)
Profile 2	64	17.158	53	14.209	122	32.708	121	32.440	123	32.976 (Above)
Profile 3	58	15.550	91	24.397	97	26.005	146	39.142	157	42.091 (Below)
Profile 4	85	22.788	104	27.882	30	8.043	59	15.818	63	16.890 (Low)
Profile 5	27	7.239	27	*7.239*	84	22.520	17	*4.558*		
Profile 6	60	16.086	64	17.158	17	*4.558*				
Profile 7	17	*4.558*	17	4.558						
Profile 8	17	*4.558*								

Note: The T2 sample consists of children assessed at both T1 and T2 (47% of the initial sample).

Time 2

The same analysis was repeated 2 years later. The bottom half of Table 1 shows the goodness of fit statistics from LPA at Time 2. The AIC value decreased from one to nine profiles, whereas the BIC value decreased from one through to eight profiles. As all profiles showed optimal entropy, profile size was taken as a determining factor (bottom half of Table 2). Two profiles of the 8-profile model were below 5% of the population; three of the 7-profile model were below 8%; two of the 6-profile model were below 7%, and one of the 5- profile model was below 5%. Therefore, the 4-profile model was selected.

Profiles description Time 2

As illustrated in Figure 1B, the four latent profiles were defined as follows:

Profile 1. *High performers* (*N* = 30, 8.04%) showed high performance across all measures (between 0.4 and 0.9 SD above average), especially on word, pseudoword reading, fluency, and reading efficiency (scores from 1.8 to 2).

Profile 2. *Above-average performers* (*N* = 123, 32.98%) obtained balanced scores above the mean on all measures (between 0.4 and 0.9 SD above average).

Profile 3. *Below-average performers* (*N* = 157, 42.09%) obtained balance below-average scores on all measures (between 0.4 and 1 SD).

Table 3. Analysis of variance for the 4-profile models in Time 1 and Time 2.

Time	Factor	1. High	2. Above-average	3. Below-average	4. Low	*F*	*Post-hoc*
1	IQ	0.447	0.117	−0.269	−0.690	36.104*	1 > 2 > 3 > 4
	PA	1.002	0.444	−0.680	−1.957	1386.077*	1 > 2 > 3 > 4
	RAN	0.606	0.801	−0.222	−0.815	66.064*	1 > 2 > 3 > 4
	VSTM	0.364	0.019	−0.041	−0.772	26.465*	1 > 2 = 3 > 4
	LK	1.228	0.007	−0.556	−1.275	438.093*	1 > 2 > 3 > 4
2	W	1.962	0.693	−0.361	−1.389	703.27*	1 > 2 > 3 > 4
	PW	1.986	0.614	−0.313	−1.364	488.76*	1 > 2 > 3 > 4
	OD	0.947	0.402	−0.234	−0.653	34.92*	1 > 2 > 3 > 4
	CS	1.187	0.699	−0.209	−1.408	208.87*	1 > 2 > 3 > 4
	FLU	1.777	0.703	−0.305	−1.460	552.75*	1 > 2 > 3 > 4
	COM	0.211	0.260	−0.006	−0.594	11.53*	1 = 2 = 3 > 4
	RE	1.871	0.528	−0.313	−1.141	215.04*	1 > 2 > 3 > 4

Abbreviations: COM = Reading Comprehension; CS = Complex Syllable reading; FLU = Reading Fluency; IQ = Intelligence Quotient; LK = Letter Knowledge; OD = Orthographic Decision; PA = Phonological Awareness; PW=Pseudoword Reading; RAN = Rapid Automatized Naming; RE = Reading Efficiency; VSTM = Verbal Short-Term Memory; W = Word Reading.
*$p < 0.001$. Values are expressed in z-scores.

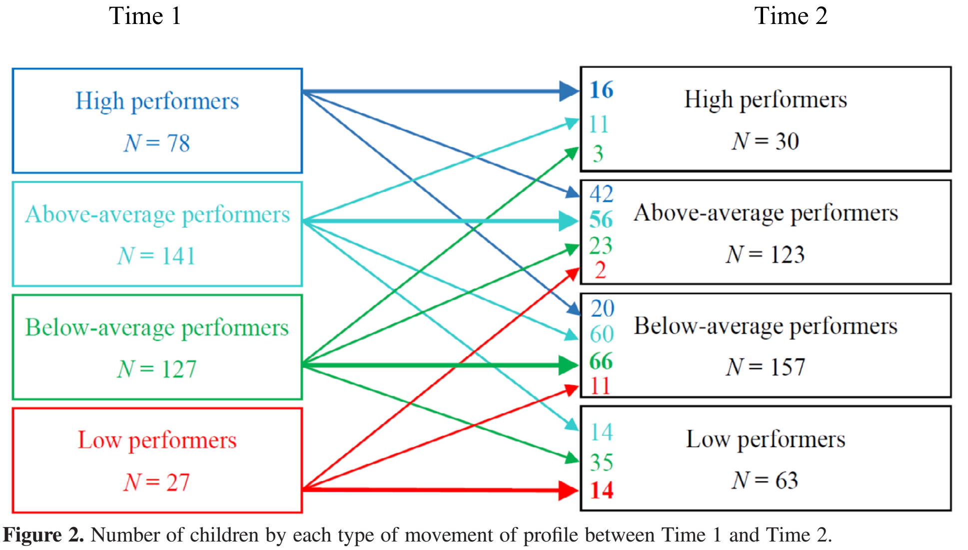

Figure 2. Number of children by each type of movement of profile between Time 1 and Time 2.

Profile 4. *Low performers* ($N = 63$, 16.89%), the high-risk profile, had scores from 1.1 to 1.4 below average on all reading measures, and 0.6 and 0.7 below average on comprehension and orthographic decision, respectively.

The bottom half of Table 3 shows the relation between the classification of profiles and each variable (W, PW, OD, CS, FLU, COM, RE). Again, the Bonferroni correction yielded significant differences between profiles for all pairwise comparisons (all *p*s <0.016), except between profiles 1–3 ($p = 1.000$), 1–2 ($p = 1.000$), and 2–3 ($p = 0.132$) in COM.

Analysis of stability between Time 1 and Time 2

For each child, permanence or movement to another profile from Time 1 to Time 2 was analysed to study the stability of profiles classification. As shown in Figure 2, 40.75% of the children (152) remained in the same profile, 13.40% (50) moved to a higher profile, and 45.84% (171) moved to a lower profile.

A surprising result was the high percentage of Below-average performers at T1 (55.6% of children, 35 out of 63) that moved to the Low performers group at T2. To understand the cause of this movement, their scores in IQ, PA, RAN, VSTM and LK were compared to the whole Time 1 group of *Below-average performers* to find that their LK scores were significantly lower ($M = -0.946$; $SD = 0.481$). Therefore, very low scores (around 1 SD) in LK seemed to be an added risk factor for developing reading difficulties when scores in PA, RAN, and VSTM were below average.

A logistic regression analysis was conducted with a dichotomous variable indicating whether a participant was classified in the same risk profile at T1 and T2 as the Dependent Variable. Data from the 373 children assessed at both time points were combined into a single dataset. Early profile classification at T1 significantly predicted reading outcome at T2 ($\chi^2(1) = 160.93$, $p < 0.001$), explaining 58.7% of the variance ($R^2 = 0.587$) with good model fit ($\chi^2 = 0$, p = 1.00). Classification accuracy reached 92.8%, with a sensitivity of 77.78% (children included in the low or below average profiles at T1 that showed low reading performance at T2, or true positives, 49 children out of 63), and a specificity of 95.81% (children classified as not being at risk at T1 that were not included in the low-reading performance at T2, or true negatives, 297 children of 310). Children in risk profiles at T1 were almost 80 times more likely to be classified as at risk at T2 (OR = 79.96, 95% CI [35.46, 180.31], $p < 0.001$). These are reliable values for predicting performance.

Discussion

This study examined whether the emergent subtypes from LPA in a sample of Spanish children conformed to the profiles predicted by the Double Deficit Hypothesis (DDH). Tracking Spanish children recruited prior to formal reading instruction (kindergarten) to Grade 2 allowed to investigate the extent to which early latent profiles were predictive of reading development in a consistent orthography. A third objective was to consider the stability of the profiles.

Characterization of profiles

The pattern of performance in kindergarten yielded four profiles that partially supported the DDH. Most children were grouped into two profiles of average to good readers: *High performers* (24%) and *Average performers* (37%). The *Below-average performers* profile included 30% of the children. Finally, we found a group of *at-risk Low performers* that fitted well with the DD profile: children showed poorer performance than the rest of the profiles, particularly in PA and LK (see Figure 1). The DD group represented 10% of participants, a figure that falls between 12–13% (Ozernov-Palchik et al., 2017; Torppa et al., 2012) and 7–8% (Furnes et al., 2019; Papadopoulus et al., 2009) previously reported for DD groups, and consistent with the prevalence rates of dyslexia among the general population (Snowling et al., 2020).

Verwimp and colleagues, with an otherwise very similar pattern of profiles to ours, reported an over-representation of *below-average performers* (40%). Note that in the Ozernov-Palchik sample, except in the RAND group, and in our sample, IQ was parallel to performance. However, in Verwimp, IQ was key to establishing two profiles of *below-average performers* (26% average IQ and 18% low IQ). These results may reflect the close relationship between IQ and family SES in the Verwimp sample, a moderator factor for reading development (Hulme & Snowling, 2015). It is likely that the distribution of SES was more heterogeneous in the Dutch than in the Spanish or English samples, which may have exacerbated the differences in the first case but weakened them in the others.

Profiles bore high resemblance in the three studies. In particular, the PA risk profile in Ozernov-Palchik, characterized by low PA and slightly low RAN, paralleled the below-average profiles in the other two studies. In addition, our profile of low performers with deficits in both PA and RAN skills was highly similar to the DD of Ozernov-Palchik, although the latter showed unexpectedly high performance in letter reading. However, despite all groups differing significantly in RAN, the performance of at-risk children in RAN tasks did not reach the levels of impairment shown in PA and LK measures. Importantly, neither Verwimp nor our study, both in consistent orthographies, yielded the pure RAND profile obtained by Ozernov-Palchik. The absence of a RAN deficit with intact PA also emerged in the Portuguese sample of Pacheco et al. (2014), who nevertheless identified two profiles corresponding to single PAD and DD, respectively.

The demands placed on the reader in orthographies of different consistency likely explain the disparity concerning the emergence of profiles. In inconsistent orthographies, phoneme-letter correspondences are especially difficult to establish because the context of the letter determines its pronunciation. Then, the onset of reading would be partially driven by the recognition of letter compounds associated with RAN skills (Araujo et al., 2015). Nevertheless, the close grapheme-phoneme correspondence of consistent orthographies makes the early stages of reading heavily reliant on the decoding skills captured by PA tasks (Landerl et al., 2013, 2019; Moll, Ramus, et al., 2014). Furthermore, compared to English, Spanish presents a simpler syllable structure – i.e., most words are constituted by CV, CVC combinations- and has a smaller vowel repertoire – i.e., 5 vs 12- that may facilitate children's awareness of phonemes and result in relatively straightforward mappings between letters and sounds (Haynes et al., 2009). The independence of RAN and PA profiles may be somehow masked when starting to read in consistent orthographies. Papadopoulus et al. (2009) could not observe differences between the three profiles in a sample of Greek children until Grade 1 (6.5 years). Similarly, Torppa et al. (2012) found that group differences were more pronounced at the age of 6.5 years than when they entered school at 3.5 years. Likewise, previous evidence for a single PAD or single RAND in Spanish came from samples including older children with dyslexia (Jiménez et al., 2008; López-Escribano, 2007), in which DD was again the most frequent profile. The joint effects of linguistic structure and orthographic consistency in the early reading stages could explain the prominence of PA to define profiles in the Dutch and Spanish samples. While a RAND profile emerged in children learning to read in the inconsistent English orthography, but not when consistent orthographies were involved.

Profiles predictability and stability

A second aim was to assess whether early profiles predicted literacy outcomes 2 years later. Consistent with the first assessment, at T2 four profiles emerged. Two groups with good literacy outcomes, High (8%) and Above-average performers (33%), and two groups with low scores on reading tasks, Below-average (42%) and Low performers (17%), emerged. A closer look to profile status at T2 showed that 67% remained in equivalent profiles, 34% above and 34% below the mean. An improvement in their performance moved 7.5% from Below-average or Low profiles to the Above-average range. Furthermore, 25% of the children who were Above-average or High performers at T1 performed significantly below the mean at T2.

Results corroborate prior findings showing significant progress in reading between kindergarten and Grade 2 (Defior et al., 2002; Poulsen et al., 2017). Spector (2005) found that over 50% of children changed their profile from Fall to Spring of Grade 1. Similarly, Steacey et al. (2014) reported that stability varied between 0.52 to 0.91 from kindergarten to Grade 1, with movements affecting particularly the single deficit profiles. In this context, the Ozernov-Palchik et al. (2017) finding that emerging profiles remained perfectly stable over time does not reflect the rapid changes that occur during the first years of reading acquisition.

A consistent finding was the greater stability of the low-performance group. Over 90% of the low performers in kindergarten demonstrated poor reading skills in Grade 2. This supports the prediction that children with deficits in both PA and RAN would show more severe and more permanent impairments than the rest of the profiles (Furnes et al., 2019; Spector, 2005).

Interestingly, some children with good skills at T1 fell behind their classmates at T2. Further exploration revealed that the T1 below-average performers that moved to the low-average group in T2 achieved significantly lower scores on LK than those who remained in the same profile, although they did not differ in PA. The contribution of LK in predicting individual differences in reading was previously reported in Spanish preschool children (De la Calle et al., 2022), and in other consistent (Torppa et al., 2013) and inconsistent orthographies (Caravolas et al., 2012; Georgiou et al., 2012), suggesting that LK may explain some variability in literacy skills not accounted for by PA. To master reading, children need both the ability to identify and manipulate word sounds and to know how letters represent phonemes (Hulme et al., 2012). In turn, LK contributes to becoming aware of the phonological structure of words. Then, children who delay in learning letters may show less progress in reading.

Limitations

Considering limitations, it should be noted that this study is a follow-up study to monitor children's progress. The measures selected for each variable were brief and focused on different cognitive variables. It implies there is no direct correspondence between measures during the first and second assessments. This was a deliberate choice since to monitor the stability of performance levels, the use of multiple predictors can be as reliable as using the same measures (Fuchs & Fuchs, 2017; Spencer et al., 2014). Moreover, our results are consistent with other studies showing that, from kindergarten to Grade 2, significant changes occur that could explain the profile movements observed here. An important limitation is that only 47% of the children were re-assessed at T2. This attrition rate reflects the difficulties to gather collaboration when that means increasing teachers' work load and it affects classroom practices. Nevertheless, our sample size was still large and representative of the general population.

Conclusions

The present findings demonstrated that neither PA nor RAN skills alone fully account for children's reading performance, suggesting that the single-deficit profiles often reported in English-speaking samples cannot be easily generalized to consistent orthographies. These results support that PA and RAN operate in combination rather than in isolation, interacting in complex ways with other cognitive and linguistic factors throughout the course of reading acquisition. This interaction appears to be modulated by the characteristics of the orthographic system, highlighting the relevance of orthographic consistency when interpreting the role of cognitive predictors in reading development. This work supports the suitability of a dimensional approach that avoids established cut-off scores and demonstrates that effective universal screening is feasible through short tasks administered by school personnel. Finally, our results are consistent with an approach in which risk for reading disability is expressed in terms of performance level rather than on the basis of specific underlying cognitive profiles. Such an approach has the advantage that children with consistently poor performances can be identified without requiring the clinical diagnosis of the condition; consequently, intervention can be provided prior to children experiencing reading failure.

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