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## Preschool emergent literacy skills as predictors of reading and spelling in Grade 2 and the role of migration background in Germany



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### ABSTRACT

Children's emergent literacy skills are essential for the development of later literacy abilities and school success. However, children with migration background often show poorer language skills in the majority language and are at a greater risk of developing literacy deficits. In addition, there is evidence for the predictive role of emergent literacy skills in reading comprehension, but there has been relatively little research concerning the association between preschool emergent literacy skills and word reading and spelling in Germany, especially for children with migration background. This study examines the associations of emergent literacy skills (vocabulary, phonological awareness [PA], letter knowledge, and rapid naming) with word reading and spelling from kindergarten to the end of Grade 2 and evaluates the role of migration background (i.e., use of the majority or minority language at home) in these associations. Data from 187 preschool children were obtained before school entry ( $M_{\text{age}} = 63.58$  months,  $SD = 4.45$ ). The results show that vocabulary and letter knowledge were strong predictors of word reading, whereas letter knowledge and PA were significant predictors of spelling. Furthermore, children's migration background was negatively associated with preschool vocabulary and PA. For children with migration background, vocabulary was a significant predictor of word reading, whereas letter knowledge was the best predictor of word reading for

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children without migration background. The results reflect the complexity of language development and the relevance of emergent literacy skills as predictors for word reading and spelling. Specific interventions should be developed to promote children's literacy abilities.

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## Introduction

Recognizing the importance of unfolding emergent literacy skills in preschool-aged children is fundamental for their academic development (Gibson et al., 2021). Longitudinal studies show that the development of preschool emergent literacy skills is critical for later achievements in literacy, encompassing essential aspects such as word reading and writing throughout primary school (Cabell et al., 2022; Ennemoser et al., 2012; Gibson et al., 2021). Here, reading comprehension, the product of language skills and word reading (Gough & Tunmer, 1986), is a key competency for academic success (Artelt et al., 2010). It is well-known that reading comprehension is shaped by a variety of factors, including reading motivation (McElvany et al., 2008), vocabulary knowledge (Ouellette, 2006), word reading (Kim, 2020b), migration background (Kim, 2020b; Melby-Lervåg & Lervåg, 2014), and cognitive skills (Kim, 2020a). However, despite the breadth of knowledge in the field, there remains a notable gap in studies that explore the interplay among early word reading, spelling, and emergent literacy skills. Specifically, investigations spanning the period from kindergarten until the beginning of primary school in Germany are still lacking. The current study aimed to fill this gap by investigating the intricate relationships among these foundational emergent literacy components during a critical developmental phase for children with and without migration background.

### *Word reading and spelling*

Reading proficiency involves the coordination and interaction of various skills, encompassing the identification of individual letters, the conversion of letters into sounds, the comprehension of word meanings, and the interpretation and understanding of the entire text (Storch & Whitehurst, 2002). Word reading can be described as the conversion of visual codes into meaningful language. The early stage of reading entails the decoding of letters, associating them with their corresponding sounds, and connecting these sounds to form individual words (Whitehurst & Lonigan, 1998). In comparison, accurate spelling means that the correct letters are written in the precise order and manner according to local convention (Martin-Chang et al., 2014; Treiman et al., 2023). Moreover, these two abilities are intercorrelated. For example, great spelling abilities are positively related to faster word reading (Martin-Chang et al., 2014).

In conclusion, developing better word reading and spelling abilities improves academic success (Kim et al., 2013; NICHD Early Child Care Research Network, 2005; Treiman et al., 2019). Consequently, identifying the precursors of word reading and spelling at an early age, as well as their interrelation, would be helpful in supporting educational achievement.

### *Emergent literacy skills as predictors of word reading and spelling*

There is a substantial volume of research that establishes a connection between emergent literacy skills and reading comprehension given that learning to read depends on the mastery of emergent literacy skills (Kim, 2020b; Lervåg et al., 2018; Martin-Chang et al., 2014; NICHD Early Child Care Research Network, 2005; Ouellette & Shaw, 2014; Vettori et al., 2023).

As proposed in the model by Whitehurst and Lonigan (1998), two domains of emergent literacy can be differentiated: inside-out skills (e.g., phonological awareness [PA], letter knowledge) and outside-in

skills (e.g., language, conceptual knowledge). Inside-out skills are related to decoding skills which allow us to translate letters into phonological representations. These skills depend on the link between letter knowledge and phonological knowledge. Outside-in skills represent oral language processes, encompassing diverse skill sets such as productive and receptive vocabulary and syntactic and semantic knowledge, which foster reading comprehension and storytelling (NICHD Early Child Care Research Network, 2005). These two skill domains are conceptually different, but there is a widely known connection between both of them.

Furthermore, other theoretical models such as the simple view of reading (Gough & Tunmer, 1986), the dual route cascaded model (Coltheart et al., 2001), and the developmental model of word recognition and naming (Seidenberg & McClelland, 1989), as well as empirical studies that investigate the development of linguistic abilities in longitudinal analyses from kindergarten until the end of primary school (Ennemoser et al., 2012; Niklas & Schneider, 2013; Sénéchal & LeFevre, 2002), explain the relations between emergent literacy skills and later literacy development.

Vocabulary knowledge is characterized by various aspects, including productive and receptive vocabulary (i.e., related to producing and comprehending), semantic features, and lexical organization (Nagy & Scott, 2000). To explain the role of vocabulary in word reading, the distinction between vocabulary breadth and depth is helpful (Ouellette, 2006). Vocabulary breadth represents the quantity of words one knows, whereas vocabulary depth focusses on the understanding of semantic representations and word meanings. Here, it can be assumed that these two measures of vocabulary have a different impact on word reading skills. For example, having a rich productive vocabulary breadth predicted visual word recognition skills, whereas a great receptive vocabulary breadth was associated with better pseudoword decoding skills (Ouellette, 2006). In addition, understanding the meaning of words (i.e., vocabulary depth) was directly associated with better reading comprehension, and indirectly associated with visual word recognition skills by fostering productive vocabulary (Ouellette, 2006). Moreover, developing a broad lexical-semantic vocabulary predicts variations in word reading abilities for primary school children given that vocabulary allows them to understand the written context (Nation & Snowling, 2004). For instance, teaching new words using semantic information (i.e., word definitions and drawings) increases the number of words spelled correctly compared with not using any semantic support (Ouellette, 2010). Consequently, the learning context of words is also crucial for word spelling. Similarly, a longitudinal study that examined the relation between preschool vocabulary and later linguistic competencies showed that infant vocabulary was a strong predictor of word reading and reading comprehension 5 years later (Duff et al., 2015).

An essential inside-out skill for word reading and spelling abilities is PA (Bus & van Ijzendoorn, 1999), which represents the ability to recognize the structure of language and to manipulate sound patterns (Sénéchal et al., 2004). The predictive role of PA in word reading and spelling has been comprehensively investigated in English-speaking countries but also in German-speaking countries (for a systematic review, see Pfost, 2015). Phonological decoding facilitates the development of specific orthographic representations for individual words, which forms the basis for rapid word recognition. Furthermore, word reading involves the transformation of letters into sounds, whereas spelling necessitates the representation of sounds through the use of letters (Kim et al., 2013). Enhancing decoding skills, therefore, initiates the process of acquiring orthographic knowledge and thus achieving fluent reading (Konerding et al., 2020). Children who possess a broader vocabulary understanding and an enhanced PA early on often exhibit improved performance in reading and spelling later in their academic journey, and they are also less prone to dyslexia (Torppa et al., 2007).

Furthermore, the associations between vocabulary and PA have been widely explored (e.g., Whitehurst & Lonigan, 1998). Here, having a broad vocabulary might increase the sensitivity to sub-lexical details, which leads to higher decoding skills (Ouellette, 2006). For instance, children's receptive vocabulary was a significant predictor of auditory perception and phoneme identification, two important aspects of PA (Krijnen et al., 2020). Similarly, some longitudinal findings showed that in kindergarten vocabulary knowledge and alphabetic knowledge were associated with greater PA and that vocabulary was a significant predictor of PA in Grade 1 (Ouellette & Haley, 2013).

Another important precursor of literacy abilities is letter knowledge, which is defined as the knowledge of letter names or alphabetic knowledge (Whitehurst & Lonigan, 1998). Both word reading and spelling require an understanding and representation of letters and letter patterns (Kim et al., 2013).

Proficiency in alphabet knowledge allows rapid conversion of written text into spoken words, reducing the time delay between reading individual letters out loud. This, in turn, supports improved reading comprehension (Ehri, 2020). These findings highlight the significance of early acquisition of grapheme–phoneme relationships (Carr et al., 2020).

The ability to rapidly recognize words from memory is invaluable as it enables readers to concentrate on comprehending the text's meaning. When readers must pause to understand the words given in the text, their reading speed is diminished and their thought process is interrupted (Ehri, 2005). Consequently, rapid naming—that is, the ability to name visual stimuli as fast as possible—is an important predictor of word identification and reading comprehension (Georgiou et al., 2016). For example, rapid naming was found to be a strong predictor of reading fluency from preschool to Grade 1 (Hoff et al., 2023).

Despite these studies, we still know little about the specific relations between early emergent literacy skills and later literacy skills, especially for spelling. Furthermore, previous studies examined the predictors individually or in tandem, and studies rarely evaluate precisely the same set of emergent literacy skills using a similar operationalization (e.g., Kim et al., 2013; Storch & Whitehurst, 2002), leading to difficulties in the comparison of findings. Consequently, a comprehensive analysis from kindergarten until primary school that encompasses a broad range of emergent literacy skills, word reading, and spelling simultaneously is hardly found in the current literature with some exceptions.

In one of the few examples of such studies, Niklas and Schneider (2013) showed that vocabulary, PA, and letter knowledge were significant predictors of word reading and spelling at the end of Grade 1. Moreover, Yang et al. (2021) identified PA, rapid naming, and vocabulary as strong predictors of early literacy skills for kindergarten children. Furthermore, Catts et al. (2015) examined word recognition precursors and their relation to later reading achievement from the beginning of kindergarten until the end of Grade 3. They found that word reading precursors were moderately related to each other and that PA was a robust predictor of word reading. Similar findings from Cabell et al. (2022) showed that in Grade 1 children's spelling and writing abilities were predicted by their early literacy skills.

### *Migration background and literacy development*

The associations between preschool emergent literacy skills and word reading and spelling for children with and without migration background have been explored in English-speaking countries (e.g., Jongejan et al., 2007; Treiman et al., 2023). However, such investigations are still lacking in Germany. Whereas there is a robust research tradition comparing language minority children in the United States, such as Spanish-speaking children (see Goodrich et al., 2013; Lesaux et al., 2010; Lonigan et al., 2013; van der Velde Kremin et al., 2019), Germany has to date established only little research on bilingual (especially Turkish–German-speaking) children and monolingual children (e.g., Becker et al., 2013; Ehl et al., 2020; Limbird et al., 2014). Therefore, it is crucial to explore the relations between emergent literacy skills and word reading and spelling for languages with a shallow orthography such as German, particularly for the comparison of children with and without migration background.

A study by Caravolas et al. (2012), which investigated similarities in the prediction of literacy skills in different alphabetic orthographies, found that PA, letter–sound knowledge, and rapid naming were significant predictors of later word reading and spelling across four different languages (English, Spanish, Slovak, and Czech). These findings indicate that emergent literacy skills are important precursors of later literacy development. Other studies compared the developmental differences in PA in languages with a deep orthography and those with a shallow orthography (see Bialystok et al., 2003; Mann & Wimmer, 2002). Here, Bialystok et al. (2003) did not find differences in PA skills among monolingual, Spanish–English-speaking, and Chinese–English-speaking children, with the exception of differences in a phoneme segmentation task. Spanish–English-speaking children outperformed monolingual children, whereas Chinese–English-speaking children were outperformed by monolinguals.

However, Mann and Wimmer (2002) found English-speaking children to outperform German-speaking children in the PA tasks at preschool, but these differences faded away in primary school.

The cause of these differences may lie in the fact that in the United States children receive formal instruction in preschool, whereas in Germany formal education begins in primary school. Therefore, these disparities seem to be the outcome of literacy exposure rather than language orthographic transparency.

Moreover, the differences in reading comprehension skills between children with and without migration background in English-speaking countries seem to fade in primary school or to disappear (for an overview, see [Bellocchi et al., 2017](#)). However, this achievement gap between children with and without migration background in Germany is still to be found in primary school (see Progress in International Reading Literacy Study [PIRLS] results in [McElvany et al., 2023](#)) and in secondary school (see Programme for International Student Assessment [PISA] results in [Lewalter et al., 2023](#)), as the latest international student assessments show.

Consequently, there is still limited understanding regarding the role these predictors play for children who learn German as their second language, especially when a larger set of emergent literacy skills is considered.

### *Children with migration background in Germany*

Given that migration background in Germany is closely associated with language abilities and academic outcomes (e.g., [Eisenwort et al., 2018](#); [Siegert & Olszenka, 2016](#)), it is also important to consider this variable in analyses concerning children's language development. According to the [Federal Statistical Office \(2022\)](#), about 41% of preschool children in Germany have a migration background (i.e., the children or at least one of their parents was not born in Germany). In Germany, children with migration background are at greater risk of developing language deficits ([Eisenwort et al., 2018](#)) and show a worse linguistic performance when compared with their peers without migration background, not just at preschool age ([Valcárcel Jiménez et al., 2023](#)) but also in primary school ([McElvany et al., 2009](#); [Vettori et al., 2023](#); [Wendt & Schwippert, 2017](#)) and secondary school ([Weis et al., 2019](#)).

Previous research suggests that children who are exposed to another language at home often show lower performance in the instruction language ([Wendt & Schwippert, 2017](#)). In fact, in Germany the majority of families with migration background speak a language other than German at home ([Autorengruppe Bildungsberichterstattung, 2016](#)). Consequently, children with a migration background (i.e., language minority children) might face an achievement gap in the German language compared with their peers without migration background.

Moreover, socioeconomic status (SES) and migration background are strongly related in Germany ([Volodina et al., 2021](#); [Weis et al., 2019](#)). Nonetheless, even after accounting for family SES, children with migration background continue to experience challenges in acquiring German as their second language, leading to lower linguistic proficiency in areas such as receptive vocabulary, PA, grammar, and reading comprehension ([Heppt et al., 2015](#); [Novita et al., 2022](#)).

While early language skills have been identified as predictors of later linguistic outcomes, there is a limited understanding of the role preschool emergent literacy skills may play for children with migration background and their acquisition of word reading and spelling abilities at primary school age. [Jongejan et al. \(2007\)](#) found that verbal working memory and syntactic awareness were stronger predictors of word reading and spelling for children without migration background, whereas lexical access (i.e., rapid naming) was of more importance for children with migration background. However, other authors did not find any differences in the predictive role of emergent literacy skills for deep and shallow orthographic systems ([Caravolas et al., 2012](#)). Nevertheless, existing research has not thoroughly addressed the question of whether these predictors can play a different role when it comes to first- and second-language learners yet.

Vocabulary is essential for understanding instructions and communication in educational settings. Children with a strong vocabulary are better equipped to comprehend lessons, follow instructions, and engage in classroom activities. Consequently, it should be easier for children with migration background to learn a new language and be proficient in reading and spelling by improving their vocabulary given that it might be easier to learn new words in the majority language than to acquire strong code-related emergent literacy skills such as a broad letter knowledge.

Some authors suggest that PA skills are easily taught and might be more sensitive to transfer from the first language, which would lead to smaller group differences in PA between children with and without migration background (Melby-Lervåg & Lervåg, 2011). Moreover, these group differences may possibly favor second-language learners depending on the orthographic system, but no differences between the two groups were found in another study (for an overview, see Bialystok et al., 2003). However, studies conducted in Germany indicate that preschool children with migration background show poorer PA skills compared with children without migration background (Dubowy et al., 2008; Valcárcel Jiménez et al., 2023).

These results would support the findings of the meta-analysis (Melby-Lervåg & Lervåg, 2014), which also found that first-language learners demonstrated tendentially better PA skills, even though these differences were not significant. The added challenges of learning two languages may outweigh the supposed benefit of being able to compare the two languages. For this reason, the predictive patterns between preschool emergent literacy and later word reading and spelling could differ for children with and without migration background.

### *The current study*

Although the impact of word reading and spelling on children's reading comprehension has been explored in longitudinal studies (e.g., Landerl & Wimmer, 2008; Lervåg et al., 2018; Treiman et al., 2023), few studies in Germany have focused on preschool children's language development while considering children's migration background. Therefore, we still need to investigate which particular preschool emergent literacy skills are precursors for later word reading and spelling development in children with and without migration background. Especially, studies are needed that examine whether the migration background is associated with later literacy abilities when preschool emergent literacy skills and other child and family characteristics are considered.

The aim of this study was to (a) examine which aspects of emergent literacy are directly associated with later word reading and spelling when being considered simultaneously; (b) test the associations among migration background, emergent literacy skills, and word reading and spelling; and (c) examine whether the direct pathway of emergent literacy to word reading and spelling differs for children with and without migration background. We used data from a longitudinal study in Germany, analyzing the children's literacy development from the end of kindergarten (1 year before school entry) until the end of Grade 2. We controlled for family SES because it is closely related to migration background (Weis et al., 2019) and for child sex because girls often outperform boys in literacy abilities before school entry, although the effect sizes are usually small (Lange et al., 2016; Lewicki et al., 2018) and some studies found significant differences only for older children but not for preschool children (Niklas & Schneider, 2012).

Based on previous research, we hypothesized the following:

*Hypothesis 1:* Since word reading requires converting letters to sounds and spelling requires representation of sounds using letters, we expected that early word reading and spelling abilities depend on specific predictors. Here, letter knowledge and PA were expected to be stronger predictors of spelling, whereas vocabulary and rapid naming should be more relevant precursors of word reading. At preschool age, children are more likely to break down spoken words into phonemes and match letters to these phonemes, instead of relying on the memorization and recall of vocabulary, when trying to identify words (e.g., Shanahan & Lonigan, 2010; Treiman et al., 2019). Having a broad vocabulary and rapid naming skills facilitates fast word identification and thus word reading (Georgiou et al., 2016).

*Hypothesis 2:* Children with migration background usually show poorer preschool emergent literacy skills, which in turn may lead to weak word reading and spelling abilities at the end of Grade 2. We expected a negative indirect association of migration background in word reading and spelling via poorer preschool emergent literacy skills.

*Hypothesis 3:* Preschool emergent literacy skills may play a different role in early word reading and spelling for children with migration background compared with children without migration background. In an exploratory approach, we tested whether vocabulary and PA are better predictors for



word reading and spelling for children with migration background than for children without migration background.

## Method

### *Participants and data collection*

To recruit participants, kindergarten directors were first informed about the project and then forwarded the provided information to the parents. In total, 187 kindergarten children aged 51 to 75 months ( $M = 63.58$  months,  $SD = 4.45$ ) and their families participated in the study. The children (48% boys and 52% girls) were recruited from kindergartens in a city in South Germany. Of these children, 27 dropped out and 28 were retained from entering school for a year. Data at the end of Grade 2 were available for 132 of the 187 children in the original sample. The 55 children who discontinued their participation in the study were significantly younger,  $t(185) = 4.835$ ,  $p < .001$ , and showed poorer rhyming skills,  $t(185) = 2.809$ ,  $p < .01$ , initial phoneme identification skills,  $t(185) = 2.452$ ,  $p < .05$ , productive vocabulary,  $t(185) = 2.749$ ,  $p < .01$ , and receptive vocabulary,  $t(185) = 2.761$ ,  $p < .01$ .

All child assessments were conducted by trained research assistants and took place in the families' homes on 1 day from May to August 2021 (last kindergarten year; Time 1 [t1]) and at children's schools or in the families' homes on 1 day from mid-June to early October 2023 (end of Grade 2; Time 2 [t2]). The visits lasted approximately 2 h and comprised assessments of child abilities while parents were asked to fill in a survey. Written informed consent was provided by the parents. Data assessment took place within the context of a large-scale longitudinal study in Germany (Project Learning4Kids; Niklas et al., 2020a, 2022) and was approved by the ethics committee of the University of Munich.

### *Measurements*

#### *Parental survey*

A parental survey was used to assess family background characteristics. The survey was translated into the most commonly spoken foreign languages in Germany (e.g., English, Turkish, Arabic, Russian, Vietnamese).

*Socioeconomic status.* We developed an index comprising the highest prestige of the parental occupation, parents' highest educational qualification, and net household income. The Magnitude Prestige Scale (Wegener, 1988) is based on 283 categories of the International Standard Classification of Occupations (ISCO) according to socially recognized prestige of the individual occupations. The scale ranges from 20.00 (unskilled laborer) to 186.80 (physician). The same range was found in our sample. On average, the highest prestige score in a family from this sample was 91.70 ( $SD = 37.80$ ), which indicates an above-average SES compared with other German samples (Niklas et al., 2020b; Novita & Kluczniok, 2022; Novita et al., 2022). About 58.00% of the parents had a university degree or a higher qualification. About 56.30% of the families earned 3419 € or more per month, and 20.7% of families the reported a net household income of 2300 € or less per month. The three indicators were z-transformed and averaged.

*Migration background.* Children were considered to have a migration background when German was not the only language spoken in the family daily. In total, 40.76% of the families in the sample ( $n = 75$ ) had a migration background, which aligns with the data from the Federal Statistical Office (2022). Within the families with migration background, 13.50% spoke in the family primarily German, 43.25% spoke German and another language and 43.25% spoke mostly another language. In total, 24 different languages were spoken by the families with migration background in our sample.

#### *Measure of linguistic abilities*

Emergent literacy skills were assessed at preschool age (t1) with an extensive battery of standardized tests in German as it is the instructional and formal language in kindergartens and schools to

which the children are exposed. Tests of word reading and spelling were administered at the end of Grade 2 (t2). See Table 1 in Results for an overview and measures of reliability.

**Productive and receptive vocabulary.** To assess productive vocabulary, 15 items from the Active Vocabulary Test for 3- to 5-Year-Old Children–Revised (AWST-R; Kiese-Himmel, 2005) were used. Children were required to name 15 picture cards—a total of 4 verbs (e.g., “throw”) and 11 nouns (e.g., “lighthouse”). Nine sets (12 items per set) from the German version of the Peabody Picture Vocabulary Test (PPVT; A. Lenhard et al., 2015) were used to assess receptive vocabulary. For this test, children were presented with four pictures and needed to point to the correct picture (e.g., “Point with your finger to foot”). Both tests were z-standardized and averaged.

**Phonological awareness.** Two subtests of the Würzburger Preschool Test (WVT; Endlich et al., 2017) measuring PA were applied. The first one was a rhyming task with 11 items. Children needed to decide which of the four words also shown in pictures did not rhyme (e.g., “See–Tee–Tisch–Klee”). The second one was an initial phoneme identification task with 11 items. Children were asked to identify and name the first sound and the remaining word (e.g., “Nose” and “Nnnn. . .ose” as answer). A scale mean was built using both test results.

**Receptive and productive letter knowledge.** Both receptive and productive letter knowledge were examined with subtests of the WVT (Endlich et al., 2017) and were assessed with 13 items each. In the receptive test, children needed to identify the correct letter among four letters presented to them (e.g., U–O–I–V: “Can you show me /O/?”). In the productive letter knowledge test, children needed to actively name letters (e.g., “What is the name of this letter?” /Z/ as answer). A scale mean was built using both test results.

**Rapid naming.** For this task, children needed to name as quickly as possible a sequence of six pictures (tree, ice, house, ball, dog, fish) that were presented in a random order three times. Each uncorrected error by naming was penalized with a 3.5-s delay in the total time (in seconds). High scores at rapid naming indicate a low rapid naming speed.

**Table 1**  
Descriptive statistics

Variable	N	M	SD	Min	Max	Cronbach's $\alpha$ / McDonald's $\omega$
Sex <sup>a</sup>	187	0.52				
Age (t1)	187	63.58	4.45	51.00	75.00	
SES <sup>b</sup>	185	−0.03	0.84	−2.89	1.32	.73/.80
MB <sup>c</sup>	184	0.41				
V productive (t1)	187	9.13	4.22	0.00	15.00	.78/.97
V receptive (t1)	187	79.06	22.26	15.00	107.00	.95/.96
PA rhyme (t1)	187	6.89	2.95	0.00	11.00	.84/.92
PA initial sound (t1)	187	6.83	3.75	0.00	11.00	.92/.93
LK receptive (t1)	187	9.57	3.33	0.00	13.00	.85/.95
LK productive (t1)	187	7.32	3.86	0.00	13.00	.89/.91
Rapid naming (t1) <sup>d</sup>	186	23.08	7.77	13.69	65.47	
WR word–pic (t2) <sup>e</sup>	132	75.70	20.25	29.00	110.00	.92
WR pic–word (t2) <sup>e</sup>	132	34.98	11.43	9.00	69.00	.96
Spelling (t2)	131	33.50	10.60	0.00	51.00	.90/.92

Note. t1, Time 1 (last kindergarten year); t2, Time 2 (end of Grade 2); SES, socioeconomic status; MB, migration background; V, vocabulary; PA, phonological awareness; LK, letter knowledge; WR, word reading; pic, picture.

<sup>a</sup> Boys = 0, girls = 1.

<sup>b</sup> Combined index of three z-transformed indicators (highest family education, highest family occupation, and adjusted household income).

<sup>c</sup> Family language: only German = 0, language other than German = 1.

<sup>d</sup> In seconds.

<sup>e</sup> Test reliability according to the authors.



**Word reading.** Word reading abilities were assessed with the Würzburger Silent Reading Test–Revised (WLLP-R; [Schneider et al., 2011](#)). For this task, children needed to read a word next to four related pictures in a row. Then, they needed to decide which picture aligned best with the word they had read and then mark the right picture. There were a total of 110 words. Children also needed to do the inverse task using the Reading Comprehension Test for Grade 1 to Grade 6 Test (ELFE; [W. Lenhard & Schneider, 2006](#)). Here, children were given a picture and needed to decide which of the four words aligned with the picture and then mark it. In total, 72 pictures were presented to the children. Both tests were z-standardized and averaged.

**Spelling.** A standardized German Spelling Test for Grades 1 and 2 (DERET 1–2+; [Stock & Schneider, 2008](#)) was used to assess children’s spelling abilities via short dictations. Children needed to write down five sentences (a total of 52 words). For each whole word correctly written, children scored 1 point, and the sum score was used for the analyses.

### Statistical analysis

Data analyses were conducted using R Studio ([R Core Team, 2022](#)). Descriptive statistics and correlational analyses are presented first. Next, path analyses were conducted using the “lavaan” R package ([Rosseel, 2012](#)) to test the predictive role of preschool emergent literacy skills for word reading and spelling. After this, children’s migration background was inserted into the model as a predictor to investigate to what extent migration background was indirectly associated with word reading and spelling via emergent literacy skills while controlling for family SES and children’s sex and age. Finally, we conducted a multigroup path analysis for children with and without migration background to investigate which are the best predictors of word reading and spelling for each group.

To evaluate the model fit, several goodness-of-fit indices were considered ([Hu & Bentler, 1999](#)): the root mean square error of approximation (RMSEA;  $\leq .06$ ), the comparative fit index (CFI;  $\geq .95$ ), and the standardized root mean squared residuals (SRMR;  $\leq .08$ ). Although we included the  $\chi^2$  goodness-of-fit statistic in our report, it is worth noting that this measure can be overly sensitive to minor model misalignments and sample size ([Chen, 2007](#)). To improve the model fit, we considered modification indices consistent with theoretical principles and incorporated these modifications systematically to achieve a satisfactory model fit ([Schumacker & Lomax, 2010](#)). The full information maximum likelihood (FIML) method was used as the estimation algorithm for missing values.

## Results

### Descriptive statistics and correlations

**Table 1** reports descriptive statistics, and **Table 2** shows the correlational analysis. Separated descriptive statistics and correlational analysis for children with and without migration background can be found in the online [supplementary material \(Tables S1 and S2\)](#).

Children who showed higher preschool emergent literacy skills at preschool developed, on average, greater early word reading and spelling abilities at the end of Grade 2. Moreover, children with better spelling abilities were also better in word reading and vice versa. Children with migration background showed significantly lower vocabulary and PA skills than children without migration background. However, these differences were not significant for letter knowledge, rapid naming, and later word reading and spelling abilities.

Moreover, children with a higher SES showed better preschool emergent literacy skills as well as higher word reading and spelling abilities. In addition, children with migration background had a lower SES compared with children without migration background. Girls showed a higher receptive letter knowledge compared with boys.

**Table 2**  
Correlational analysis

Variable	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Sex <sup>a</sup> (1)	—													
Age (2)	.03	—												
SES <sup>b</sup> (3)	-.11	-.14 <sup>+</sup>	—											
MB <sup>c</sup> (4)	.01	.05	-.34 <sup>**</sup>	—										
V productive (5)	.01	.01	.54 <sup>*</sup>	-.69 <sup>**</sup>	—									
V receptive (6)	.01	.09	.48 <sup>**</sup>	-.53 <sup>**</sup>	.77 <sup>**</sup>	—								
PA rhyme (7)	.00	.01	.51 <sup>**</sup>	-.36 <sup>**</sup>	.53 <sup>**</sup>	.58 <sup>**</sup>	—							
PA sound (8)	.13	.03	.35 <sup>**</sup>	-.24 <sup>**</sup>	.49 <sup>**</sup>	.52 <sup>**</sup>	.46 <sup>**</sup>	—						
LK receptive (9)	.21 <sup>**</sup>	-.01	.23 <sup>*</sup>	-.08	.34 <sup>**</sup>	.34 <sup>**</sup>	.36 <sup>**</sup>	.56 <sup>**</sup>	—					
LK productive (10)	.05	.00	.16 <sup>*</sup>	.02	.23 <sup>**</sup>	.27 <sup>**</sup>	.33 <sup>**</sup>	.57 <sup>**</sup>	.73 <sup>**</sup>	—				
Rapid naming <sup>d</sup> (11)	-.04	-.05	-.11	.04	-.27 <sup>**</sup>	-.24 <sup>**</sup>	-.17 <sup>*</sup>	-.23 <sup>**</sup>	-.20 <sup>**</sup>	-.24 <sup>**</sup>	—			
WR word–pic (12)	.14	.04	.36 <sup>**</sup>	-.07	.42 <sup>**</sup>	.53 <sup>**</sup>	.43 <sup>**</sup>	.35 <sup>**</sup>	.37 <sup>**</sup>	.34 <sup>**</sup>	-.30 <sup>**</sup>	—		
WR pic–word (13)	.04	.10	.33 <sup>**</sup>	-.01	.35 <sup>**</sup>	.45 <sup>**</sup>	.36 <sup>**</sup>	.34 <sup>**</sup>	.40 <sup>**</sup>	.39 <sup>**</sup>	-.27 <sup>**</sup>	.81 <sup>**</sup>	—	
Spelling (14)	.06	-.05	.31 <sup>**</sup>	-.05	.33 <sup>**</sup>	.42 <sup>**</sup>	.44 <sup>**</sup>	.40 <sup>**</sup>	.42 <sup>**</sup>	.41 <sup>**</sup>	-.24 <sup>**</sup>	.62 <sup>**</sup>	.58 <sup>**</sup>	—

Note.  $N = 129$ – $187$ . SES, socioeconomic status; MB, migration background; V, vocabulary; PA, phonological awareness; LK, letter knowledge; WR, word reading; pic, picture.

<sup>a</sup> Boys = 0, girls = 1.

<sup>b</sup> Combined index of three z-transformed indicators (highest family education, highest family occupation, and adjusted household income).

<sup>c</sup> Family language: only German = 0, language other than German = 1.

<sup>d</sup> In seconds.

<sup>+</sup>  $p < .10$ .

<sup>\*</sup>  $p < .05$ .

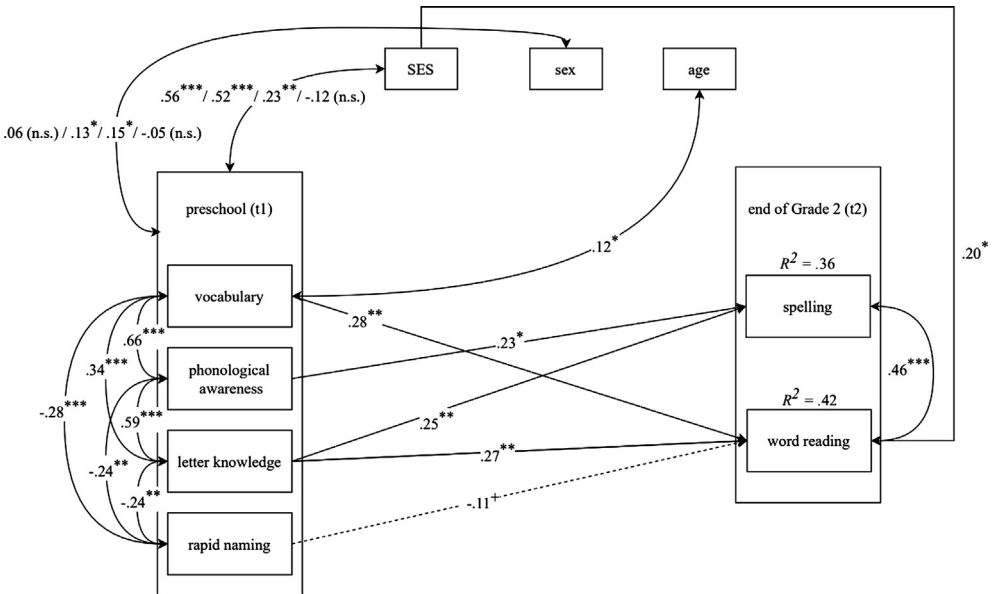
<sup>\*\*</sup>  $p < .01$ .

Preschool emergent literacy skills as predictors of word reading and spelling

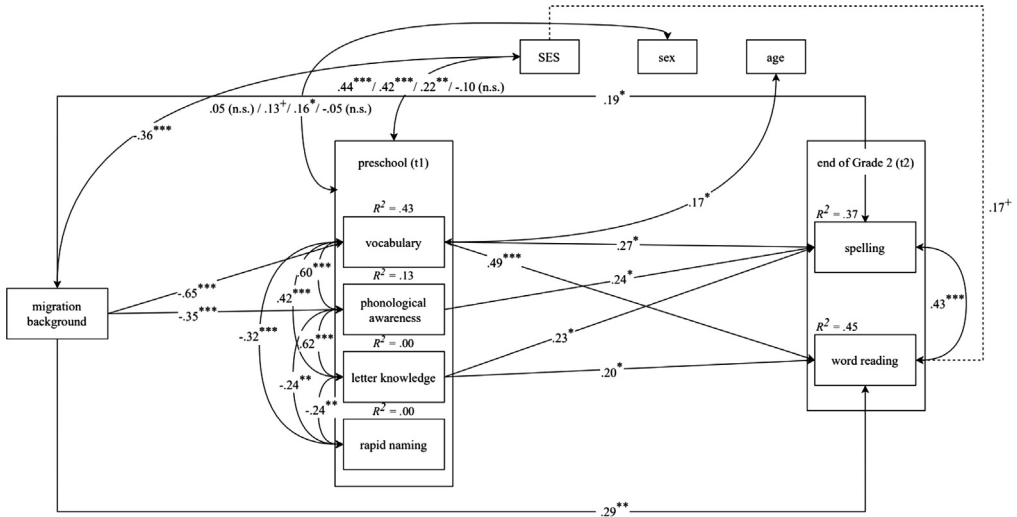
A path analysis (see Fig. 1) was performed to investigate the associations between preschool emergent literacy skills and word reading and spelling (Hypothesis 1). Here, we controlled for children’s sex, age, and family SES. The goodness-of-fit indices indicated a good model fit,  $\chi^2(3) = 4.609$ ,  $p = .203$ ; RMSEA = .054, CFI = .996, SRMR = .032. When all four preschool emergent literacy skills were considered simultaneously, preschool letter knowledge ( $\beta = .25$ ,  $p < .01$ ) and PA ( $\beta = .23$ ,  $p < .05$ ) were the only significant predictors for spelling, with the model explaining 36% of variance in spelling. Furthermore, preschool letter knowledge ( $\beta = .27$ ,  $p < .01$ ) and vocabulary ( $\beta = .28$ ,  $p < .01$ ) predicted word reading at the end of Grade 2 significantly, with 42% of the variance explained by the model. Rapid naming was not a significant predictor of word reading and spelling in this model. All preschool emergent literacy skills were strongly intercorrelated. Similarly, word reading and spelling were closely related ( $r = .46$ ,  $p < .001$ ). In addition, children with a higher SES showed better emergent literacy skills and word reading abilities. Girls, in comparison with boys, were better in PA and letter knowledge skills at preschool age.

Migration background, emergent literacy skills, and word reading and spelling

In a next step, we added children’s migration background to the path model to investigate to what extent children’s family language was indirectly associated with later word reading and spelling via preschool emergent literacy skills (Hypothesis 2). Here, the goodness-of-fit indices showed an acceptable model fit,  $\chi^2(7) = 15.456$ ,  $p < .05$ ; RMSEA = .080, CFI = .984, SRMR = .039. To improve the model fit, modification indices aligning with theory were considered. Consequently, migration background was entered as a predictor of later word reading and spelling, with goodness-of-fit indices showing a good model fit,  $\chi^2(5) = 4.948$ ,  $p = .422$ ; RMSEA = .000, CFI = 1.000, SRMR = .029. The  $\chi^2$  differentiation test indicated a significant  $p$  value,  $\chi^2(2) = 10.508$ ,  $p < .01$ , suggesting the second model to be better fitting. Fig. 2 shows the results of the path model.



**Fig. 1.** Preschool emergent literacy skills as predictors of word reading and spelling at the end of Grade 2: Structural equation path model with preschool predictors. This model shows the relations between emergent literacy skills before school entry (t1) and word reading and spelling at the end of Grade 2 (t2). Standardized regression coefficients are shown. Only marginally significant relations (dotted lines) and significant relations (solid lines) are displayed. SES, socioeconomic status; n.s., not significant. Sex (boys = 0, girls = 1). \* $p < .10$ ; \*\* $p < .05$ ; \*\*\* $p < .01$ ; \*\*\*\* $p < .001$ .



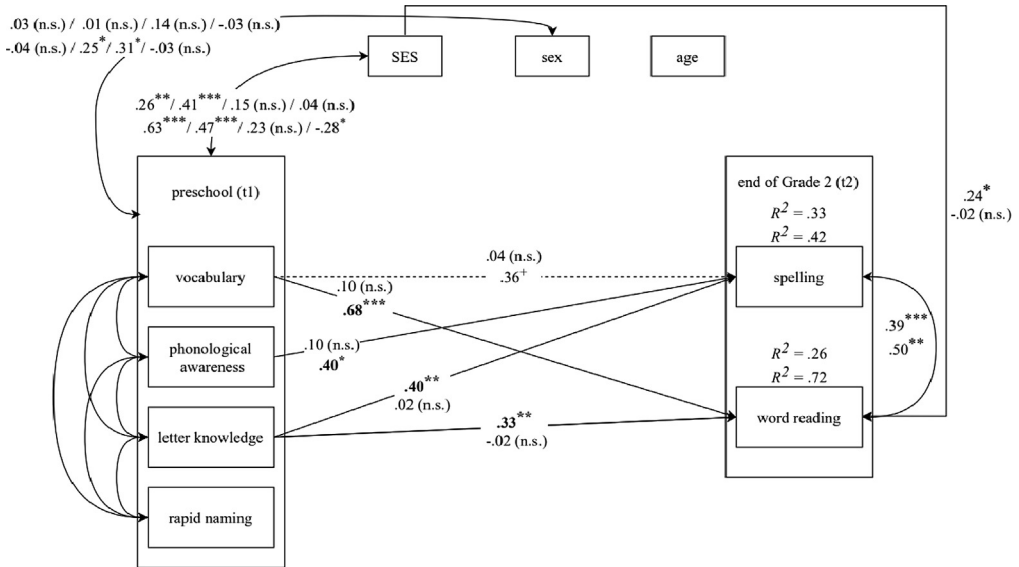
**Fig. 2.** Preschool emergent literacy skills as predictors of word reading and spelling at the end of Grade 2 considering children's migration background: Structural equation path model with preschool predictors. This model shows the relations between migration background, emergent literacy skills before school entry (t1), and word reading and spelling at the end of Grade 2 (t2). Standardized regression coefficients are shown. Only marginally significant relations (dotted lines) and significant relations (solid lines) are displayed. SES, socioeconomic status; n.s., not significant. Sex (boys = 0, girls = 1). Migration background (without = 0, with = 1).  $^{*}p < .10$ ;  $^{*}p < .05$ ;  $^{**}p < .01$ ;  $^{***}p < .001$ .

Children's migration background was negatively associated with vocabulary and PA at preschool age but was positively correlated to word reading and spelling at the end of Grade 2. Moreover, a higher SES was associated with better vocabulary, PA, and letter knowledge skills. In addition, children with migration background lived in families with a lower SES, and girls performed better than boys in the letter knowledge tests.

For the associations between emergent literacy skills and word reading and spelling, similar results as represented in Fig. 1 were found. Letter knowledge ( $\beta = .23, p < .05$ ), PA ( $\beta = .24, p < .05$ ), and vocabulary ( $\beta = .27, p < .05$ ) were significant predictors of spelling at the end of Grade 2. In addition, significant indirect effects of migration background on spelling, mediated via vocabulary ( $\beta = -.18, p < .05$ ) and via PA ( $\beta = -.09, p < .05$ ), were found. For word reading, letter knowledge ( $\beta = .20, p < .05$ ) and especially vocabulary ( $\beta = .49, p < .01$ ) were significant predictors. In addition, an indirect effect of migration background on word reading, mediated by preschool vocabulary, was found ( $\beta = -.32, p < .001$ ). These negative indirect effects were of similar size compared with the positive direct effects and equalized them.

To investigate which preschool emergent literacy skills are strong predictors of word reading and spelling for children with and without migration background, respectively (Hypothesis 3), we conducted a multigroup path analysis (see Fig. 3). Here, the goodness-of-fit indices showed a good model fit,  $\chi^2(6) = 7.547, p = .273$ ; RMSEA = .063, CFI = .995, SRMR = .043.

For children without migration background, letter knowledge was the only significant predictor of spelling ( $\beta = .40, p < .01$ ) and word reading ( $\beta = .34, p < .01$ ), and 33% of variance in spelling and 26% in word reading were explained by the model. On the contrary, for children with migration background, PA ( $\beta = .40, p < .05$ ) was the only significant predictor of spelling, and here 42% of the variance was explained by the model. For children with migration background, vocabulary ( $\beta = .68, p < .001$ ) predicted word reading at the end of Grade 2, and 72% of the variance in word reading was explained by the model. However, the multigroup comparison showed significant differences only between children with and without migration background in the prediction of word reading by vocabulary and letter knowledge. Here, vocabulary was a significantly stronger predictor for children with migration background ( $\beta$  difference = .58,  $p < .05$ , confidence interval (CI) [.140, .924]), whereas letter knowledge



**Fig. 3.** Preschool emergent literacy skills as predictors of word reading and spelling at the end of Grade 2 for children with and without migration background. This figure illustrates the results of a path model using a multigroup analysis. It shows the relations between emergent literacy skills before school entry (t1) and word reading and spelling at the end of Grade 2 (t2). Standardized regression coefficients are shown for children with (below) and without (above) migration background. Correlation coefficients between preschool emergent literacy skills are not displayed due to space constraints. Marginally significant relations (dotted lines) for at least one group and significant relations (solid lines) are displayed. Not significant relations for both groups are not displayed. SES, socioeconomic status; n.s., not significant. Sex (boys = 0, girls = 1). <sup>+</sup>*p* < .10; \**p* < .05; \*\**p* < .01; \*\*\**p* < .001.

( $\beta$  difference =  $-.33$ ,  $p < .05$ , CI [ $-.667$ ,  $-.050$ ]) was a stronger predictor for children without migration background. Regarding the differences in the control variables and emergent literacy skills between children with and without migration background, we found that the associations among vocabulary, SES, and PA, as well as among PA, letter knowledge, and rapid naming, were significantly greater for children with migration background.

**Discussion**

This study evaluated the predictive role of preschool emergent literacy skills in early word reading and spelling abilities at the end of Grade 2. In addition, the role of migration background in these relations was explored. This study offers crucial findings to foster children’s linguistic development.

When several preschool emergent literacy skills are included in a predictive model simultaneously, vocabulary and letter knowledge were significant predictors of word reading, whereas PA and letter knowledge were significant predictors of spelling. In line with prior studies (Cain & Oakhill, 2014; Kim, 2020b; Niklas & Schneider, 2013; Yang et al., 2021), these results suggest that developing an extensive vocabulary and letter knowledge helps to foster early word reading by quickly identifying words and thus understanding their meaning. Furthermore, having an early broad knowledge of the alphabet and a better understanding of sounds in words allows children to improve their spelling, learning to write words correctly and avoiding common mistakes in the German language (Stock & Schneider, 2008).

Contrary to other studies (Georgiou et al., 2006; Hoff et al., 2023; Landerl & Wimmer, 2008; Niklas & Schneider, 2013; Treiman et al., 2019; Yang et al., 2021), rapid naming was not significantly associated with spelling at the end of Grade 2 when controlling for child and family characteristics, vocabulary, PA, and letter knowledge. However, our study shows a negative marginally significant relation

between rapid naming and word reading. This aligns with some findings, showing that rapid naming had a direct effect on word reading (Georgiou et al., 2016).

All four emergent literacy skills in this study were significantly correlated with early word reading and spelling. When analyzing the data considering each emergent literacy skill as a unique predictor, all of them predicted word reading and spelling significantly. Moreover, word reading and spelling were strongly correlated. Consequently, fostering predictors of word reading or spelling should also be beneficial for both literacy abilities. In fact, exploring the connections among emergent literacy skills such as vocabulary, letter knowledge, and PA is also essential because these skills may, for example, not only influence word reading directly but also have indirect effects such as vocabulary fostering PA after controlling for letter knowledge (Ouellette & Haley, 2013). Consequently, future research should first explore longitudinal relations between different emergent literacy skills to understand their influence on later word reading and spelling abilities.

In addition, this article provides further results on the current research of migration background, investigating its associations with preschool emergent literacy skills and early word reading and spelling at primary school in Germany. In our study, and in line with prior findings (Dubowy et al., 2008; Fröhlich et al., 2013; Novita et al., 2022), children with migration background showed lower vocabulary and PA skills at preschool age and lived in families with a lower SES. However, children with and without migration background did not differ in their letter knowledge and rapid naming.

Contrary to some studies (Vettori et al., 2023; Wendt & Schwippert, 2017), children with migration background showed similar word reading and spelling abilities at the end of Grade 2 compared with children without migration background. The positive direct associations of migration background with word reading and spelling shown in the model equalized the negative indirect associations via poorer vocabulary and PA, resulting in similar word reading and spelling abilities between children with and without migration background. A possible explanation for this might be that in specific situations bilingual students have demonstrated to possess an advantage when acquiring an additional language given that it might foster cognitive and linguistic processes that enhance foreign language acquisition (Maluch & Kempert, 2019). In this case, children with migration background might overcome preschool disadvantages and show similar abilities as their peers without migration background.

Furthermore, Niklas and Schneider (2017) found similar associations among migration background, preschool emergent literacy skills, and early and later reading and spelling in a large German sample, indicating that children with migration background seem to catch up during primary school. There could be some kind of reversed Matthew effect (see also Niklas et al., 2012) that may be due to specific support and training in kindergarten provided for children with weaker emergent literacy skills and thus to many children with migration background. These result patterns also align with findings of studies conducted in English-speaking countries that did not find differences in reading comprehension between children with and without migration background in primary school (for an overview, see Bellocchi et al., 2017).

Nevertheless, letter knowledge and vocabulary were significant predictors of word reading, whereas letter knowledge, PA, and vocabulary were significant predictors of spelling, when migration background was considered. Taken together, it seems that migration background is negatively associated with some emergent literacy skills (vocabulary and PA) at a younger age, but there is no strong association with early word reading and spelling at the beginning of primary school. Here, it would be relevant to investigate which factors (e.g., family, school, teaching, interventions) contribute to this compensation to be able to derive practical implications to support children's early language development. For example, the latest international student assessment in Germany showed, that migration background was no longer a significant predictor of reading competence in Grade 4, when children's home literacy environment and reading self-concept were considered (McElvany et al., 2023).

Furthermore, the associations between emergent literacy skills and word reading and spelling were analyzed for children with and without migration background. For children without migration background, letter knowledge was a significant predictor of both word reading and spelling. For children with migration background, vocabulary was a significant and very strong predictor of word reading, whereas PA was the only significant predictor of spelling. When examining the paths from emergent literacy to word reading and spelling, children with and without migration background differed significantly in only two aspects. Preschool vocabulary was exclusively a significant predictor of word



reading for children with migration background, whereas letter knowledge was only a significant predictor of word reading for children without migration background.

These findings do not necessarily contradict the results of Caravolas et al. (2012), who investigated these associations only for children without migration background and identified emergent literacy skills as predictors of literacy development for alphabetic deep and shallow orthographies. However, the predictors of reading competence might differ when second-language acquisition is considered.

Especially for children with migration background who are at greater risk of developing language deficits (Eisenwort et al., 2018), a broad vocabulary is crucial for reading comprehension (Lervåg & Aukrust, 2010). Here, a greater vocabulary could also facilitate more advanced cognitive processes, which are necessary for later reading comprehension (Ouellette & Shaw, 2014). In addition, a better vocabulary can foster emergent literacy skills such as PA (Ouellette, 2006; Ouellette & Haley, 2013) that are important for word reading and spelling (Pfost, 2015). In comparison, for children without migration background who already show greater vocabulary and PA skills, letter knowledge was the most important emergent literacy skill for both early word reading and spelling. A plausible explanation for this difference could be that children with migration background rely more on a rich vocabulary to read correctly. Here, a greater vocabulary may support their decoding process when reading and spelling. In contrast, children without migration background might rely more on the structure of words, such as morphemes, to read and spell correctly. In this case, a greater letter knowledge would support the recognition of word structures.

The dual route cascaded model from Coltheart et al. (2001) would partially support these assumptions. Here, children with migration background would depend more on the lexical route: The more words in the majority language are memorized as a whole (i.e., as a word image), the better children's later word reading. Children without migration background would profit similarly from a great vocabulary; however, given that they already have a greater vocabulary in the majority language, letter knowledge is more important for them, in particular, when reading and spelling unknown words for which the sublexical route is used.

However, it should be considered that Coltheart et al.'s (2001) model focuses on reading acquisition in readers' native language. Although different learning processes may be used during word reading and spelling, these might not differ in the quality of processing, and therefore children with and without migration background demonstrate similar spelling and word reading skills. Future research should investigate how literacy acquisition develops and identify potential processual differences for children with and without migration background.

Another interesting finding is that the relations between SES and PA, as well as the relations of PA with vocabulary, letter knowledge, and rapid naming, were stronger for children with migration background. Consequently, emergent literacy skills seem to be strongly intercorrelated for children with migration background, which should be considered when developing interventions to foster these skills for preschoolers. In addition, more research is needed on the development of competencies in the majority language for children with migration background.

### Limitations

Despite the interesting findings, this study has several limitations. The small sample size did not allow more sophisticated statistical modeling in which additional variables, such as cognitive skills and working memory that are associated with emergent literacy skills, may have been included (Kim, 2020a; Melby-Lervåg, 2012; Zhang & Malatesha Joshi, 2020). In fact, the perfect model fits (see RMSEA and CFI values) are likely caused by the few degrees of freedom instead of by a perfect fit (Goretzko et al., 2024). Consequently, replications with larger samples would help to test our findings. The results also should be interpreted with caution as differences concerning age and emergent literacy skills were found between children who dropped out and children who continued with their participation until Grade 2.

In addition, there may have been an effect of social desirability given that the use of German language at home might be considered as a favorable indicator of integration for families with migration background (Dubowy et al., 2011). However, the differences in effect sizes among different operationalizations (e.g., nationality vs. family language) are generally relatively small (Dubowy et al.,

2011). A more precise operationalization of different forms of migration background, taking specific cultural and language differences into account, would lead to more detailed results. Given the small sample size, this study did not account for various ethnic backgrounds and cannot draw conclusions from the particular cultural influences on emergent literacy skills.

Another issue was the multicollinearity among the predictors, especially among PA, vocabulary, and letter knowledge. Exploratory separate analyses that considered each emergent literacy skill as an individual predictor showed that all four of these variables predicted word reading and spelling significantly. When including all emergent literacy skills in the model simultaneously, vocabulary, PA, and letter knowledge remained significant predictors. However, we checked for multicollinearity, and the variance inflation factor values below 5.00 (Salmerón et al., 2018) indicated that multicollinearity was not a major issue in our data.

Moreover, the vocabulary assessment focused only on vocabulary breadth and not on depth. Differentiating between these two components of vocabulary can lead to significant insights about the role of vocabulary in word reading and spelling (Ouellette, 2006). We also assessed word recognition but not word comprehension as an aspect of word reading. A more specific and broader approach to measure emergent literacy skills and early word reading and spelling would improve our understanding of these relations.

#### *Future research and implications*

Despite these limitations, our findings underline the need not only to identify which specific preschool emergent literacy skills predict word reading and spelling but also to understand potential specific group differences in these relations. The identification of predictors of word reading and spelling offers the possibility to develop interventions and educational programs for families with and without migration background.

Parental support via institutional interventions in kindergarten for children with migration background (e.g., Grob et al., 2019) might foster the acquisition of emergent literacy skills. Furthermore, interventions at preschool age may also promote emergent literacy skills (Thomas et al., 2020). In their review, Hulme et al. (2020) showed that school interventions also can improve children's emergent literacy skills. Similarly, app-based learning interventions (Niklas et al., 2020a) or computerized graphophonological training programs (Konerding et al., 2020) may have a long-term impact on literacy development. In addition, developing spelling trainings that involve the presence of semantic information instead of reading trainings should improve accurate word spelling (Ouellette, 2010).

#### *Conclusions*

This study demonstrates the importance of emergent literacy skills, especially vocabulary, PA, and letter knowledge, for children's literacy development and provides new insights for research on migration background. Emergent literacy skills at preschool age predict early word reading and spelling at the end of Grade 2. Here, vocabulary was of utmost importance for children with migration background, whereas letter knowledge was the only significant predictor for children without migration background. Longitudinal studies following young kindergarten children until the end of primary school would be beneficial for providing insights into the development of children's linguistic and literacy abilities and for identifying causal factors of social disparities for children with and without migration background.

#### *CRedit authorship contribution statement*

**María Valcárcel Jiménez:** Writing – review & editing, Writing – original draft, Formal analysis. **Melike Yumus:** Writing – review & editing. **Tina Schiele:** Writing – review & editing, Investigation. **Anna Mues:** Writing – review & editing, Investigation. **Frank Niklas:** Writing – review & editing, Supervision, Project administration, Investigation, Funding acquisition, Data curation, Conceptualization.

## Data availability

Data will be made available on request.

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## Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.jecp.2024.105927>.

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