



INTRODUCTION

Developmental dyslexia and culture: the impact of writing system and orthography

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Received: 17 August 2023 / Accepted: 17 August 2023 / Published online: 26 August 2023
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Abstract Developmental dyslexia is recognized worldwide. However, there are cultural differences between countries in dyslexia-related issues, including assessment practices and intervention. Language and orthography are essential cultural factors that influence both literacy acquisition and the possible manifestation of developmental dyslexia. These differences in orthographies impose different culturally specific demands on cognitive processes involved in reading acquisition and performance. This special issue focuses on the current research on different writing systems and orthographies and on the theoretical perspectives arising from findings from different orthographies. Thereby, the impact of writing systems and orthographies (e.g., English, Italian, Japanese, Portuguese, Chinese, Bahasa Melayu/Malaysian and braille script) on unimpaired and impaired reading acquisition is considered with regard to the following literacy-relevant issues: (1) the assessment of reading skills and reading-relevant cognitive functions, (2) neurobiological findings and (3) intervention. The

findings and theoretical perspectives are discussed within the Multiple-level Framework of Developmental Dyslexia, which is described in detail in a contribution of the special issue.

Keywords Alphabetic · Syllabic · Logographic · Writing · Environmental factors · Second language

Introduction

While oral language has an evolutionary basis, written language, i.e. literacy, is a cultural achievement, an acquired skill that must be taught and learnt. During this procedural learning process (Nicolson and Fawcett, 2018), pre-existing cognitive functions, amongst them visual and auditory processing, memory, oral language, and motor skills, are modified and coordinated to form literacy-specific cognitive procedures (Lachmann and van Leeuwen, 2014) which then become automatized after prolonged intensive, instruction-guided practice (Froyen et al. 2009; Lachmann and van Leeuwen, 2008). This leads to significant structural and functional changes in the brain (e.g., Dehaene et al., 2010; Dehaene et al., 2015). Since these changes are the result of a culturally initiated learning process and are not evolutionary predetermined like the involved pre-existing cognitive

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functions, this process can be seen as an *acculturation of the brain*.

In practice, developmental dyslexia is mainly diagnosed by impairments in the acquisition process and the resulting population-relative deficits in reading and writing performance (see Lachmann et al., 2022). However, developmental dyslexia is categorically defined by an underlying neurodevelopmental deficit that is universal and not culturally determined. This contradiction is resolved by considering that the biological deviations first affect the pre-existing cognitive functions, which in turn are involved in the literacy-specific procedures to different extents depending on the culture.

Ultimately, literacy acquisition requires learning how language is expressed in written form. Thus, the extent to which the various pre-existing cognitive functions play a role in literacy acquisition also depends on the characteristics of both the language and the writing system (see Lachmann and Bergström, 2023, for a review). Despite this, most studies on literacy acquisition and developmental dyslexia focus on alphabetic writing systems (Share, 2014) and this carries the risk of inappropriate generalizations of the finding across different languages and writing systems (e.g., Lachmann et al., 2022). Meanwhile, there is a growing body of findings on non-alphabetic writing systems (e.g., Chinese: Ho and Bryant 1997; Hung et al. 2018; Tzeng et al. 2018; Devanagari: Skeide et al., 2017; Japanese: Inoue et al., 2022; Wydell, 2019; Korean: Bae et al., 2022) and an increasing number of cross-orthography comparative studies designed to test the applicability of existing reading-related and dyslexia-related models in non-alphabetic languages (e.g., Joshi, 2018; Peng et al., 2021).

This special issue focuses on the current research on different writing systems and orthographies, as well as theoretical perspectives discussing findings from different orthographies. In particular, the impact of writing systems and orthographies on unimpaired and impaired reading acquisition is considered with regard to a variety of literacy-relevant factors.

Lachmann and Bergström (2023) introduce a multiple-level framework of developmental dyslexia that considers multiple levels of a causal pathway upon which a given genotype is expressed and hierarchically transmitted from one to the next level. The first levels are the *neurobiological level* and the *information processing level*. These are not literacy-

specific and develop over an evolutionarily determined time course before literacy acquisition. These levels provide the cognitive functions required to form the literacy-specific procedure as a consequence of explicit instruction. Only the abilities acquired by this instruction will be referred to by the authors as literacy skills (*skill level*). Deficits at this skill level can lead to problems at the next level, the *academic achievement level*. Problems here result in inadequate outcomes according to social demands. The authors argue that deficits at the academic achievement level are the major expression of developmental dyslexia. The assumed fundamental deficit at the neurobiological level is expressed as a disorder only due to the failure of learning a cultural technique and therefore the diagnosis of developmental dyslexia would not be made if this failure did not exist or if the deficient skills were not of utmost cultural and social relevance. It could thus be argued that developmental dyslexia is a kind of “cultural disorder”. At the end, the deficits at skill and achievement levels may then lead to emotional, behavioral and social problems at *secondary level*.

The transition from one level to the next is increasingly influenced by individual traits and environmental factors, both moderated by cultural conditions. Hence, various risk and protective factors (e.g., Dzhambov et al., 2023) at different levels within the assumed causal pathway lead to a considerable variance of symptom expression and severity between societies, subgroups and individuals. The transition between levels is neither unidirectional nor inevitable. Therefore, prevention and intervention can mitigate transitions from one level to the next. Lachmann and Bergström (2023) assign various evidence-based theories and findings regarding deficits to the different levels of the proposed framework. Moreover, the moderating cultural impact on the transmission from the information processing level to the skill level is further elaborated based on a review of the findings on the influences of different writing systems and orthographies, which impose different culture-specific demands on skill acquisition and performance (e.g., Wydell, 2023). In the review, the findings from phonologically based alphabetic writing systems and from the morphosyllabic Chinese writing system are contrasted.

Marinelli et al. (2023) compared the pattern at the skill level, in particular reading errors based on a

classification used by Hendriks and Kolk (1997), in two groups of elementary school children: one learning the transparent Italian orthography, the other the opaque English orthography. They found that English readers produced more errors resulting in words (but not in non-words) compared to Italian readers. Moreover, detailed error analyses revealed that the pattern of errors differed between the groups. This indicates a reliance on different reading strategies depending on the transparency of the orthography, i.e., on a cultural factor. When children made reading errors in both words and nonwords, Italian-reading children showed more sounding-out behavior and syllabifications compared to English-reading children. This indicates that Italian-reading children used a strategy that was rather slow and in which they approached reading gradually (e.g., “lim..., limou..., limousine”) which indicates a greater reliance on the phonological (sub-lexical) route. English-reading children, in contrast, showed more non-word lexicalizations (“infection” instead of “tinction”), word substitutions (“lemon” instead of “limousine”) and, in low-frequency words, more phonological-visual (e.g., more than the half of the letters are correct, e.g. “limoustine” instead of “limousine”), morphological (“limousines” instead of “limousine”) and semantic errors (“car” instead of “limousine”). This indicates a greater reliance on the lexical route in English. The authors point out that the use of an error coding scheme can effectively capture differences in the reliance on the phonological (sub-lexical) and lexical routes as a function of orthography as a cultural factor. Furthermore, an analysis of reading errors could be informative regarding modifications after an intervention for children with developmental dyslexia in different orthographies.

Faísca et al. (2023) examined the heterogeneity in the cognitive profile of university students with a childhood dyslexia diagnosis in the semi-transparent orthography of Portuguese. In comparison to age-matched typical readers, the university students with dyslexia showed deficits of very large effect sizes at the skill level (word and pseudoword fluency, word decoding) and deficits with medium to large effect sizes at the information processing level, i.e., in phonological processing (phonological awareness, alphanumerical RAN, phonological short-term and working memory), in visual attention and vocabulary. There were no deficits in visuospatial working memory, processing speed and most nonverbal reasoning

measures. For the students with developmental dyslexia, a cluster analysis identified two groups differing at skill and information processing level. One group of adults with developmental dyslexia outperformed the other in most measures at skill and information processing level (except visual attention span, one phoneme awareness measure and some nonverbal reasoning measures). Moreover, when compared to typical readers, this group showed no deficits in most measures at the information processing level (especially in phonological processing, but also in visual attention span, verbal working memory, and vocabulary) and even had higher performance in visuospatial working memory and in some nonverbal reasoning measures (reflecting an individual trait factor, see Lachmann and Bergström, 2023). According to Faísca et al. (2023), this suggests that, at least in highly educated adults with developmental dyslexia with systematic exposure to reading and writing, the cognitive strengths of some individuals may have been used to compensate for reading difficulties. This supports the role of environmental and individual factors on the transition of a neurodevelopmental deficit to the skill level, and thus the manifestation of developmental dyslexia across the life span.

Harris et al. (2023) compared the phonological decoding skills in blind braille-reading and sighted print-reading adults to evaluate the assumption that the high complexity of the braille script interferes with the phonological self-teaching mechanism, thus resulting in higher prevalence rates of developmental dyslexia in blind compared to sighted readers. In contrast to this expectation, braille readers outperformed sighted readers in phonological decoding skills. Harris et al. (2023) concluded that other script-independent factors, such as a lack of exposure to environmental print or higher preterm birth rates in blind born children, might contribute to the higher prevalence rates found in other studies.

Pye and Chan (2023) investigated the use of a dynamic testing paradigm in an artificial language as a “language-free method” to assess reading skills in an adult sample in Malaysia. This is important as traditional reading tests may be more influenced by cultural factors (e.g., education, vocabulary), making it difficult to diagnose developmental dyslexia in a complex linguistic background of simultaneous multilingualism and multiliteracy. The dynamic test used in this study (artificial symbol-sound learning

paradigm) captures the ability to acquire basic decoding skills in a more culture-fair manner. The research question was whether this test reflects reading performance or related difficulties only in alphabetic orthographies or also in logographic/morphosyllabic orthographies (specificity vs. universality of reading acquisition across different orthographies). In addition to the dynamic reading test (skill level), the authors assessed reading performance using a lexical decision task in the three different orthographies used in Malaysia: the alphabetic orthographies Bahasa Melayu (transparent) and English (opaque), and the logographic/morphosyllabic orthography of Chinese. Furthermore, phonological awareness in Bahasa Melayu (information processing level) was tested and potential reading difficulties were assessed using a questionnaire. Hierarchical linear regression analyses revealed that the dynamic test scores predicted the potential reading difficulty assessed by the questionnaire, beyond phonological awareness, but not the reading skills measured by the lexical decision task. Importantly, dynamic test scores did not differ depending on the orthography in which literacy was first acquired. However, the group that first acquired literacy in alphabetic orthographies (English and Bahasa Melayu) outperformed the group that first acquired literacy in the Chinese morphosyllabic orthography in the English lexical decision task. This might support the assumption that the dynamic test may be appropriate for readers across orthographies because the language of first literacy does not affect the performance. However, the dynamic test scores only predicted a potential reading difficulty in the group who acquired literacy first in alphabetic orthographies. Pye and Chan (2023) concluded that the dynamic test might be a “suitable assessment tool for multilinguals, but that further research is required to determine its utility, especially in non-alphabetic languages”.

Pamei et al. (2022) discuss the construct validity of international literacy measures by focusing on culture-specific (including orthography-specific) reasons for performance differences (skill level) in the Programme for International Student Assessment (PISA) across countries. First, Pamei et al. (2022) review results that question the measurement invariance of the PISA test. This invariance, however, is required for valid cross-cultural comparisons. The high proportion of low-performing students and the stable or even

declining trends in performance over a 10-year-period due to cultural factors are illustrated using three middle-income low-performing countries in Southeast Asia (Indonesia, Malaysia and Thailand). It is concluded that differences in reading scores and thus in the proportion of low performing readers in various countries can be attributed to cultural factors related to the orthography (e.g., diglossia resulting in the test language of PISA not corresponding to the spoken native language; longer texts or lack of spacing in some orthographies, which increases reading times), but also to other individual and environmental factors, such as economic, social and cultural status and attitudes towards learning or teaching methods. This highlights the relevance of the specificity of orthographies/scripts and languages for reading and reading impairment. Finally, suggestions are given for improving the construct validity of reading tests in the context of cross-cultural comparisons. Contextual factors need to be considered when developing tests and interpreting test results.

Wydell (2023) discusses if phonological awareness is crucial for reading acquisition and for explaining developmental dyslexia in the Japanese writing systems: logographic Kanji and two forms of the syllabic Kana (Hiragana, Katakana). Therefore, after a comprehensive overview on the complex Japanese orthographic system, Wydell (2023) reviews the following findings: (1) reading acquisition in Kanji compared to Kana, (2) the relevance of phonological awareness in reading acquisition and (3) findings on deficits at skill level and information processing level in developmental dyslexia in alphabetic and non-alphabetic orthographies. After that, the behavioral and neurobiological findings on the manifestation of developmental dyslexia in a bilingual English-Japanese adolescent are synthesized. The identified impairments at the neurobiological level and in phonological processing transferred to the skill level only in English and not in Japanese. The poor reading skills in English, but good reading skills in Japanese Kana and Kanji, are explained by the different demands on the reading process in the orthographies using the Hypothesis of Granularity and Transparency (Wydell and Butterworth, 1999). Wydell (2023) concludes that phonological awareness is not as important for early literacy acquisition and for the manifestation of developmental dyslexia at skill level in the Japanese orthography as it is in the alphabetic English orthography. Therefore, it

is important to develop intervention programs for children with developmental dyslexia that are tailored to the Japanese orthography, rather than adapting them from programs used in alphabetic orthographies (especially in the English orthography).

Considering ten dimensions of orthographic complexity (linguistic distance, spatial arrangement and non-linearity, visual uniformity and complexity, historical change, spelling constancy, omission of phonological elements, allography, dual purpose letters, ligaturing, inventory size; Daniels and Share, 2018), Moore et al. (2023) discuss the impact of different orthographic features (e.g., transparency, syllable structure, morphological complexity, visual complexity, prevalence of homophones and homographs, diglossia) on reading acquisition and the manifestation of difficulties at the information processing level and the skill level. They review relevant findings in different writing systems: alphabetic writing systems (Finnish, Spanish, German, Portuguese, French, English), abjads (Arabic, Hebrew), the featural script of Korean (i.e., Hangul) and the morphosyllabic writing system of Chinese. In their synthesis, several cognitive functions at the information processing level are identified as relevant for unimpaired and impaired reading acquisition. These functions may be universal across orthographies (e.g., phonological processing, especially rapid automatized naming), or specific and dependent on particular orthographic features of the respective orthographies (e.g., orthographic knowledge in Finnish; stress awareness in Spanish; morphological awareness/abilities in Finnish, Arabic, Hebrew, Chinese; visual abilities in Arabic, Chinese, Korean). Moore et al. (2023) conclude that the ten dimensions proposed by Daniels and Share (2018) are important considerations in reading instruction as well as in the diagnosis and intervention of developmental dyslexia. Apart from the two dimensions important for all orthographies (i.e., spatial arrangement, non-linearity), some dimensions (i.e., spelling constancy, historical change, allography, dual purpose letters) are more relevant for alphabetic orthographies while other dimensions (i.e., linguistic distance, partial loss of phonological elements, ligaturing, inventory size, visual uniformity and complexity) are more relevant for non-alphabetic orthographies.

Conclusions

The studies reported in this special issue show the diversity of research interests in reading-related topics, including developmental dyslexia. A wide variety of writing systems and orthographies are addressed; there are orthographic-comparative studies, a study focusing on a semi-transparent alphabetic orthography, and theoretical papers that synthetically compare different writing systems and orthographies. Various topics are focused on, from the assessment of literacy skills and literacy-related cognitive functions to the assessment of developmental dyslexia and intervention. Furthermore, the different levels of the proposed multiple-level framework of Lachmann and Bergström (2023) were considered, addressing abilities at the skill level (decoding skills, ability to learn decoding skills, reading errors) and the information processing level (especially phonological awareness), as well as findings at the neurobiological level. All the topics presented here as well as the theories and models addressed can be located within the framework. The influence of the writing systems and orthographies on the transition from one level to the next is clearly elaborated. However, research mostly focuses on one or two of these levels. For future research, it would be interesting to examine more comprehensive studies on the entire causal pathway.

The cultural factors addressed in this special issue relate predominantly to the various writing systems and orthographies. However, there are also orthography-independent cultural factors such as economic status, milieus, educational system, diglossia, multilingualism and multiliteracy in a country that have a significant impact on literacy acquisition and the manifestation of developmental dyslexia. These factors should be given greater consideration in future studies in order to examine their specific impact on transitions from one level to the next.

Furthermore, in a multilingual and multicultural world, the following exemplary questions could also be studied in the future to address the transition to the academic level and the secondary level: What impact does culture have on secondary symptoms? What role does migration play in developmental dyslexia? Are there differences in L1 and L2 as language of instruction? How is dyslexia manifested, diagnosed and treated in multilingual systems (such as India,

Catalonia, Bask, Canada, Switzerland, Luxembourg, Belgium)?

Acknowledgements The authors would like to thank Christopher Allison for valuable comments and remarks.

Author contributions TL and KB contributed to the manuscript. TL had the idea for the proposed model and further conceptualized it together with KB.

Funding Open Access funding enabled and organized by Projekt DEAL. No funding was received to assist with the preparation of this manuscript.

Declarations

Conflict of interest The authors declare no competing interests.

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