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Abstract

Purpose: This paper is a systematic literature review which examines what intervention programmes have been developed over the last 17 years to support dyslexic young school aged children between five and thirteen years of age, across a range of languages. The focus is on both reading and spelling interventions alongside the use of contemporary technology to enhance outcomes. **Method:** Through an extensive search of the Google Scholar database and subsequent relevant academic journals, 16 potential articles were identified with 11 meeting the requirements to be included in the review. The requirements were as follows: interventions had to focus on reading and spelling, participants were aged between 5 and 13 years old, and the interventions had to be focused on dyslexia only. There was a particular interest in the socio-emotional impact of the interventions. **Results:** 11 articles were reviewed. The results showed how (i) 1:1 interventions are effective for dyslexic children, (ii) multi-sensory and technological interventions can increase performance motivation in classroom environments, (iii) scaffolding is effective in improving spelling and reading abilities in the context of grapheme-phoneme correspondences. Conclusions: although important, reading and spelling do not constitute overall learning development. Consideration must be given to the language system used, especially when learning English as an additional language. Technological interventions can also positively impact motivation of dyslexic learners.

Keywords: dyslexia, orthography, reading, spelling, phonological, technological interventions, socio-emotional impact, grapheme, phoneme

Review

This systematic review aims to examine what intervention programmes have been developed over the last 17 years to support school aged children between the ages of five and thirteen with Dyslexia. Technological interventions, such as apps and games that focus on text-errors, have been used to support these students. These interventions have been published in psychology journals and demonstrate that phonological and orthographical interventions have a positive effect on reading and spelling ability and that emerging technological interventions increase comprehension ability, reduce anxiety and impact motivation levels. The studies and interventions included are contemporary and cover the period between 2005- 2022. The studies in this review utilise a range of languages, alongside English. Generally, interventions worked well across the whole age range of students, but older children were able to apply activities holistically across their studies more so than younger children. For a full list of summarised studies see appendix A.

Dyslexia, at its core, is a difficulty with learning to read, decode and spell. Children with dyslexia struggle to generalise reading and spelling to words they have not seen before (Snowling, Hulme and Nation, 2020). Dyslexia is seen as a neurological difference that affects one's ability to read and spell fluently and accurately. Dyslexic individuals can struggle with phonological awareness, verbal processing speed and verbal memory (Rose, 2009). In the English language, phoneme-grapheme mapping is inconsistent making it difficult for children learning to read (Snowling, Hulme and Nation, 2020). The orthography of English is less transparent than other languages; there are many inconsistencies, making it more challenging to learn than other European languages, such as German, Dutch, Italian and Spanish (Seymour and Erskine, 2003). Children acquire a phonological awareness (how words sound) and a connection to semantics (what words mean). They then develop maps

between orthography (how words are spelt) , phonology and meaning (Snowling, Hulme and Nation, 2020).

The majority of studies in this review centre around Developmental Dyslexia (DD) and its subtypes: difficulties with phonology, reading and spelling exceptional words (e.g. 'yacht'), or difficulties with both (mixed dyslexia) (Terzopoulos, Niolaki and Masterson, 2020). DD is one of the most prevalent learning challenges, accounting for 80% overall (Lerner, 1989; Yang et al., 2022). Children with DD are prone to academic and social anxiety along with low self-esteem, more so than their typically developing peers (Zuppardo et al., 2021).

Reading and spelling interventions

Learning to read is a fundamental task but is not always easy for children especially if they have a specific learning difficulty (Rasmitadila et al., 2021). Throughout primary school, children should be taught the basics of reading with phonics skills, grammatical knowledge, word decoding and letter patterns (Nation and Angell, 2006). Children with dyslexia benefit from sustained reading interventions covering both declarative (facts about something) and procedural elements of reading (e.g. step by step instructions) (Tilanus, Segers and Verhoeven., 2019).

A study by Tilanus, Segers and Verhoeven (2016) compared 54 Dutch-speaking dyslexic children between the ages of 7-8 with 61 students without reading challenges aged between 6-8 to examine whether a grapheme-phenome correspondence (GPC) based phonics study would improve reading and spelling abilities in the dyslexic children. It is important to note the measures used in this study were the Dutch language versions. Pre-test results showed that dyslexic children were significantly behind their peers on GPC ability test, which involved reading 36 phrases on cards as fast as possible. The intervention lasted twelve

weeks, with each session lasting 45 minutes and consisting of five stages. Children were asked to practice at home for 100 minutes each week. In the first 10 minutes of the session, a mnemonic card was introduced with a spelling on which was broken down by the assessor in an interactive way, which included repetition of the word, splitting the word into phonemes, linking a symbolic scaffold to each phoneme and writing this down, then checking the mapping between the phoneme, symbolic scaffold and written grapheme. The symbolic scaffold in this study attributed each GPC category to a symbol. For example, a short vowel was symbolised as a hyphen (-), and consonants were symbolised as less than sign (<). An example used in the paper was the Dutch word 'bom' ('bomb' in English), which would be scaffolded as < - < [b o m]. This guided task allowed for reading and spelling practice whilst simplifying the complex Dutch GPC categories (Tilanus, Segers and Verhoeven., 2016).

Following this, the focus shifted to reading where graphemes and words were named using flashcards. Finally, the child would work on an activity that tied this together with a focus on syllabic words. The intervention was successful, with dyslexic children scoring higher in some cases than children without reading challenges on post-test. The use of scaffolds in this intervention allowed the cognitive load to be reduced for the children when simplifying GPCs, by breaking down complexities and slowly introducing new elements, with support. In terms of word decoding, equal progress was made between groups. This also demonstrates the benefits of a 1:1 setting throughout the intervention. A similar study by Tilanus, Segers and Verhoeven (2019) with a minimally larger sample of 122 and an additional 36 sessions was conducted, again concluding that interventions focusing specifically on word decoding, and conducting a declarative approach, is beneficial for children with Dyslexia. This intervention was sustained and found children's initial reading and spelling abilities affected their response to the training, which predicted reading and spelling outcomes at post-test.

Similarly, Berninger et al., (2013) aimed to identify effective support programmes for spelling and word decoding over a period of five months. 24 English speaking dyslexic children were split into two equal size support groups and went through four stages of tests. After baseline tests, groups A and B received, at Step 1, teaching on phoneme-grapheme correspondences (alphabetic principle training). In step 2, Group A received alphabetic principle training specific for spelling (phonemes to graphemes correspondences); Group B received phonological awareness training not directed at spelling. In step 3, Group A received further alphabetical principle teaching for both spelling and reading. They also received orthographic (whole-word) spelling strategies and orthographic working memory training (the latter to support reading comprehension), whilst Group B continued to receive alphabetical principle training for reading. Finally, in Step 4, alphabetic principle training was withdrawn for both Groups. Group A received morphological training and continued with orthographic working memory training, whilst Group B received orthographic strategies training.

The analyses revealed that introducing orthographic strategies and memory training at Step 3 to Group A significantly and uniquely contributed to spelling. However, when alphabetic principle training was withdrawn at Step 4, this was detrimental for decoding rate improvement, suggesting both orthographic and phonological training are necessary to support challenges with decoding. Orthographic memory training was also found to improve reading comprehension by improving the rate of letter decoding, providing some evidence of the role of working memory training for whole-words in improving phonological difficulties. The addition of morphological training did not seem to improve decoding and there was no advantage of the alphabetical principle training for both spelling and reading over reading only. The first might have resulted from the fact that morphological training is a novel training, not received before in school, and of limited duration or because children with

dyslexia have mainly difficulties with orthography and phonology rather than morphology. The latter might be because Group A, unlike Group B, did not receive phonological awareness training, which showcases its importance for improving dyslexics' decoding skills.

A range of cognitive skills and processes informs reading accuracy (Snowling, Hulme and Nation, 2020). Dębska et al., (2022) aimed to examine cognitive challenges in dyslexia and the predictive value of cognitive skills for reading in a sample of dyslexic Polish primary school children. Children were tested on a variety of measures assessing cognitive skills, mainly phonological awareness, implicit learning and rapid automatised naming (RAN). The intervention took place over two sessions where all standardised tests were pen-paper format and the rhythm perception, tone comparison, visual attention span and implicit learning were computer based. Visual attention span is number of distinct visual elements that can be processed at once within the first 200 milliseconds of presentation (Liu et al., 2023). The study found that the most common deficits for Polish primary school children were phonological (51%) and RAN (26). These challenges coexisted in 14% of the children, predicting their reading attainment, which is in line with previous research. Interestingly, 26% of children with dyslexia presented no deficit in cognitive ability, despite having a severe reading impairment (Dębska et al., 2022). This study took place in a Polish school. It is worth noting there are similarities in the way in which Polish and English are taught; Polish is also largely phonics based in the first stages This is in line with Rose (2009) who demonstrated dyslexic children often hold strengths in areas such as design and problem solving.

Systematic phonics programs have been developed to assist children with learning to read and spell and have been found to be more effective than non-structured techniques (de Graaff et al., 2009).

Phonics through spelling schemes are particularly effective for children with dyslexia (van Rijthoven et al., 2021a). van Rijthoven et al (2021b) aimed to identify the effectiveness of a phonics through spelling intervention by analysing their phonological, morphological and orthographical spelling errors before and after the intervention, whilst investigating a possible compensatory role of semantics, in the Dutch language. The children in this study spoke Dutch as their first language. The intervention lasted, on average, 27 weeks and consisted of weekly 45-minute sessions with a clinician. It is worth noting that both the intervention and feedback given from the clinician were tailored, as much as was feasible, to each child's individual needs. Dyslexic and non-dyslexic children worked through a range of reading and spelling measures based upon phonological awareness, phonemes and RAN. Post-intervention, all dyslexic children had reduced spelling errors across all areas, with a reduction in orthographic errors being most notable. Children with better developed semantic representations of words demonstrated less errors overall than children with less developed semantics, demonstrating that semantic stimulation and specific interventions could benefit children with, or at risk of, Dyslexia. (van Rijthoven et al., 2021b).

The orthography of English is considered 'deep' as its grapheme-phoneme (word to sound) correspondence are inconsistent and complex, yet in German it is considered shallow (or transparent) as they are consistent with their spelling sounds (Seymour and Erskine, 2003). In English, letters often correspond to more than one sound. For example, 'c' can correspond to the 'K' sound in 'cat' and also the 'S' sound in 'certain', whereas in German, letters often correspond directly to sounds (Miller, 2019 p.3). Furthermore, the letter 'a' is pronounced the same in German words such as 'Hamster' and 'Parade' yet, in the English version of 'hamster' and 'parade', the 'a' sound is pronounced differently (Ise and Schulte-Körne, 2010).

Ise and Schulte-Körne (2010) set out to examine the effectiveness of an orthographic spelling intervention for German Dyslexic children , with and without training. They used a range of spelling and reading measures whereby each group of children were split into two conditions measuring reading and spelling ability in study 1 and spelling ability and knowledge of orthographic spelling rules in study 2. In study 1, treatment group children were given spelling training to support their learning of the complex rules surrounding long and short vowels in German. This is not often taught in the regular classroom due to the complexity of the language. The training was highly structured and conducted by a therapist. They were subsequently given a spelling and a reading test to assess their knowledge. In the control group, children were given no training. The same was done in study 2, only with the addition of an orthographic knowledge questionnaire with eleven questions at the end of the intervention, measuring the children's knowledge of long and short vowels. In this control group, children were given training, with a delayed start. Findings indicated that, in study 1, children showed significant improvement in reading ability and, in study 2, a knowledge of orthographic spelling rules. In both groups, children who received the full training programme demonstrated better results. The training intervention was demonstrated as effective for learning a transparent language such as German, thus could be applied to others that are similar, such as Dutch. However, similar interventions may require adjustment for extrapolation to the English language due to the differences in orthography and subsequent difficulties children experience (Ise and Schulte-Körne, 2010).

Overall, phonics interventions have been proven to assist dyslexic learning, as has 1:1 intervention. Different languages present different challenges for learners due to their differing orthographies (Seymour and Erskine, 2003). However, generally, it is clearly evidenced that symbolic scaffolds are effective in improving outcomes in the classroom, allowing words and phrases to be broken down into manageable steps (Tilanus, Segers and

Verhoeven, 2016). Allowing children to develop semantic representations of words through tailored interventions has a positive impact on their ability to decode and spell, highlighting the importance of this being facilitated and sustained throughout primary school teaching (van Rijthoven et al., 2021b). Children can be aided by resources such as decision trees to help them visualise options for spellings in particular, which is a common feature across training interventions (Ise and Schulte-Körne, 2010).

Multi-sensory interventions

As identified by Snowling, Hulme and Nation (2020) the English language is complex, especially when learning it. A 'one size fits all' approach to classroom learning is not effective for allowing students to reach their academic potential, especially for those with developmental differences (Newman, 2019). Multi-sensory learning help compensate for auditory and visual 'sensory channels' by stimulating other senses and are helpful for dyslexic learners (Høien & Lundberg, 2012). Therefore, Flaten Jarsve and Tsagari (2022) investigated the process of learning English as a second language with Dyslexia and investigating how multi-sensory techniques can impact spelling and motivation. English is a compulsory subject on the Norwegian curriculum; thus children are exposed to the language from an early age. Five dyslexic participants, three of whom also had co-occurring difficulties, were tested in this study. Participants engaged in eight lessons which corroborated with the Norwegian curriculum and involved songs, rhymes, guessing and look-cover-write-check type activities. Results showed that English proficiency was developed, and motivation levels increased across all participants. A 38% increase of correctly identified words was identified across participants, demonstrating that multi-sensory interventions are an effective way at tackling challenging topics for Dyslexic children. However, the co-occurrent difficulties three of the children presented with complicated the intervention,

corroborating research by Snowling and Hulme (2011) demonstrating that dyslexic children with additional learning needs would benefit from tailored interventions.

Technological interventions

Contemporary dyslexia interventions have focused on technology. Technological tools can be beneficial for helping improve reading ability and facilitating action in children with dyslexia (Degirmenci, Baglama and Yucesoy, 2020). Technology can build on individual's strengths and assist them to achieve in-line with their peers (Jing and Chen, 2017).

Throughout the Coronavirus (COVID-19) pandemic, schools were forced to shut down and move their learning online which meant a global shift to interactive technology and, for some dyslexic students, assistive technology (Mishra, Gupta and Shree, 2020; Forteza-Forteza et al., 2021). Cancer et al (2021) aimed to compare the effectiveness of telerehabilitation and in-person rehabilitation for rhythm-based reading interventions for Italian dyslexic children during the COVID-19 induced lockdown. They used a computerised training program to produce music-based reading exercises which tested multiple sub-processes such as syllabic blending, syllabic reading, word recognition and sub lexical decoding. Each task had a basic melodic rhythm coupled with a visual cue. Thirty children were assigned to either an in-person or online condition. Results showed that reading speed and accuracy improved after the intervention in both conditions, regardless of the training type, and positive effects were noted up to three months post-intervention , demonstrating the effectiveness of telerehabilitation.

In general classroom settings, text-to-speech assistive technology is the most commonly used to assist children with dyslexia (Jing and Chen, 2017). Bonifacci et al (2022) aimed to evaluate the effects of a text-to-speech intervention to alleviate mind-wandering and distraction in the classroom for Italian speaking children. 70 participants were presented with

two narrative texts and ten reading comprehension questions as a follow-up. Dyslexic and non-dyslexic children were split into groups and matched on gender and socioeconomic status. The children were split into two conditions- self-paced reading and text-to-speech. All dyslexic children were occasional users of assistive technology. At unpredictable intervals, children were asked to rate on a scale from 1 to 5 how focussed they were on the task. Overall, dyslexic children showed more mind-wandering on the self-paced task rather than the text-to-speech and better comprehension scores in the assistive condition. For both groups, text-to-speech demonstrated better results, strengthening the case for it to be rolled-out across classrooms.

Children with dyslexia experience high levels of stress and anxiety due to interactions with teachers who consistently underestimate their ability, leading to self-doubt, self-esteem problems, thus generating strong negative emotions surrounding their academic performance and general wellbeing (Alexander-Passe, 2008; Jordan and Dyer, 2017). Therefore, Plakopiti and Bellou (2014) investigated the psychological impact of anxiety during reading comprehension in both electronic and printed format for dyslexic pupils and to identify the best configuration options in word processing that maximised outcomes for reading and spelling comprehension tasks. The children, aged between 9-12, were given two texts , one printed and one electronic on Microsoft Word. Each were adapted to their specific cognitive level depending on the school grade they were in . In the Microsoft Word condition, children could choose their own background, text size and font based on what was available. Each condition lasted for 20 minutes and children were asked to answer relevant text-based questions. The majority of children (N=6) chose a yellow background with blue font, followed by a yellow background and black font (N=5). Children were tested on their anxiety levels before and after each text. The results showed that electronic text and giving the children choice over how their work was presented lowered anxiety levels and improved

comprehension scoring, versus the printed text. The attractiveness of the electronic text increased motivation levels and lower contrast backgrounds reduced fatigue on the eye, reducing cognitive processing loads; the low luminance screen was also contributing factor to improving reading comprehension outcomes. Although this intervention was effective, the given tasks did not follow the school-curriculum, thus results could differ in a classroom environment (Plakopiti and Bellou, 2014).

Text presentation is essential for helping dyslexic pupils, as appropriate presentation reduces both anxiety and cognitive load. Rello et al (2014) recognised that dyslexic children struggle with long, complicated words. To tackle this, they aimed to improve spelling through accessible, electronic play activities utilising existing dyslexia apps- 'DysEggxia' and 'Word Search'. Training exercises were entered into the apps based on existing in-text errors made by dyslexic children. The children , who were from Spain and were Spanish speakers and writers, were split into two groups and completed both conditions over an 8-week period during 20-minute sessions. In phase one, group A played 'DysEggxia' and group B played 'WordSearch' which is not error-based. In phase two, conditions were reversed. Unlike Plakopiti and Bellou (2014), this intervention was based on the school curriculum and children were presented with words they saw whilst learning in the classroom. Results found that doing exercises based on dyslexic errors helped dyslexic children to improve their spelling skills, as the rate of errors-per-word decreased by 20% when playing DysEggxia compared to WordSearch. However, it was identified by the authors that it is not conclusive whether this change would be effective long term. Reading skills were not improved due to the spelling-focused nature of the study (Rello et al., 2014). Furthermore, the results are valid only in the context of the Spanish language. A further study would need to be conducted to extend the results for English children due to the challenging nature of the English orthography. The 'DysEggxia' software also has exercises in English (Rello et al., 2014).

Conclusion and implications

The purpose of this systematic review was to examine the intervention programmes that have been created over the past 17 years to assist young school-aged children between the ages of 5-13, with Dyslexia in their learning. The focus of the review is on spelling and reading interventions alongside the consideration of technological interventions to further enhance learning outcomes.

The interventions included in this review are from multiple different languages (English, Dutch, Spanish, German, Italian and Polish) which have different orthographies, alongside each country having a different way of teaching. The transparency of European languages, in general, allows children to acquire literacy skills easier than children whose first language is that of a deep orthography, such as English (Seymour and Eysnick, 2003). Despite this, all Dyslexic learners benefit from extra instruction to enhance reading and spelling outcomes as they tend to struggle with complicated words (Rello et al., 2014). Scaffolding skills are particularly useful to their development (Tilanus, Segers and Verhoeven, 2016; 2019). Dyslexic children benefit from interventions that are tailored to their cognitive level (Plakopiti and Bellou, 2014; van Rijthoven et al., 2021b) as it allows them to make appropriate progress without being overwhelmed.

Contemporary technology, such as utilising computerised learning, text-to-speech software and specific Dyslexia-based apps that aim to enhance reading and spelling, are useful to children with DD not only bettering their outcomes, but also enhancing motivation and excitement for and within the learning environment and reducing anxiety (Plakopiti and Bellou, 2014; Rello et al., 2014; Bonifacci et al., 2022). Outside the classroom, Dyslexic children can face large challenges in their social circles due to their functional challenges and low self-esteem (McNulty, 2003). Therefore, although not a diagnostic feature of Dyslexia,

socio-emotional effects are at the forefront of contemporary debates about the impact on learning (Forteza-Forteza et al., 2021). The evidence presented in this review highlights technological interventions positively impacts the child's learning experience, thus demonstrating also the positive socio-emotional impact such interventions can have surrounding learning.

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