DEA - An Innovative Technological Tool for Personalized Linguistic Training for Italian Children with Developmental Dyslexia

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ABSTRACT (ENGLISH)

In this paper, we illustrate a research project using advanced technological tools to improve the linguistic and reading skills of Italian children diagnosed with developmental dyslexia (DD) aged between 8 and 11. Besides the well-known reading and spelling difficulties, DD is characterized by marked linguistic deficits especially at phonological and morphological level, negatively impacting the child's reading abilities and directly affecting text comprehension. Recent studies have shown the effectiveness of linguistic interventions in enhancing phonological and morphological awareness in DD children and improving their reading skills. However, access to such linguistic programs is not free from important barriers; in particular, high costs and difficulties in customizing training programs make it imperative to implement new accessible technological tools. In this context, we developed the DEA (Dyslexia Exercises Application) training program, a modular web application that offers interactive and highly personalized linguistic activities. The ongoing study involves 30 DD Italian children who participate in a 10-week training three times a week for 20-minute sessions. The program includes phonological and morphological exercises with increasing difficulty created with AI support. It allows the therapist to monitor the child's progress and provide a tailored reinforcement program based on their needs. DEA provides individualized and highly accessible training programs to support reading development in children with DD, helping the therapist create specific learning tracks based on the participant's linguistic and cognitive skills.
Keywords: Developmental Dyslexia; Linguistic Training; Morphological and Phonological Awareness; Technology in Dyslexia Training; Interactive Exercises.

ABSTRACT (ITALIANO)

DEA – Uno strumento tecnologico innovativo per il potenziamento linguistico personalizzato per bambini italiani con dislessia evolutiva.

In questo articolo illustriamo un progetto di ricerca che utilizza soluzioni tecnologiche avanzate per migliorare le competenze linguistiche e le abilità di lettura di un gruppo di bambini con diagnosi di dislessia evolutiva (DE) di età compresa tra gli 8 e gli 11 anni. Oltre alle ben note difficoltà nella letto-scrittura, la DE è caratterizzata da marcati deficit a livello fonologico e morfologico, che influenzano negativamente le abilità di lettura con conseguenze dirette anche sulla comprensione del testo. Studi recenti hanno dimostrato l'efficacia di interventi linguistici mirati a potenziare la consapevolezza fonologica e morfologica nei bambini con DE per migliorare le loro abilità di lettura. Tuttavia, l'accesso ai percorsi di potenziamento linguistico non è esente da barriere importanti: in particolare, costi elevati e difficoltà nella personalizzazione dei programmi rendono necessaria l'implementazione di nuovi strumenti tecnologici di marcata accessibilità. In questo contesto, abbiamo sviluppato un programma di training linguistico DEA (Dyslexia Exercises Application), una applicazione web modulare che offre attività linguistiche interattive e altamente personalizzate. Lo studio è attualmente in corso e coinvolge 30 bambini con DE, che partecipano a 10 settimane di training, tre volte a settimana per sessioni di circa 20 minuti. Il programma include esercizi per il potenziamento fonologico e morfologico con difficoltà crescente creati con il supporto dell'AI e permette al terapista di monitorare i progressi del singolo partecipante in modo da fornire un programma di potenziamento personalizzato sulla base delle sue esigenze. DEA consente interventi personalizzati e accessibili per supportare lo sviluppo della letto-scrittura nei bambini con DE, permettendo al terapista di creare percorsi specifici sulla base delle competenze linguistiche e cognitive del partecipante.
Parole chiave: Dislessia Evolutiva; Potenziamento Linguistico; Competenza Morfologica e Fonologica; Tecnologia per la Dislessia; Esercizi Interattivi.

1. INTRODUCTION

Specific Learning Disabilities (SLD) are neurodevelopmental disorders impacting the development of academic skills and affecting 5-15% of children and adolescents globally(DSM-5, First, 2014; 3.5% in Italy, Pido' et al., 2021). Developmental dyslexia (DD) is the most prevalent of these disorders and is characterized by remarkable impairments in the automatization of academic skills such as reading, writing, and arithmetic skills despite adequate intellectual ability, absence of neurological deficits and appropriate literacy exposure (DSM-5). Besides severe reading and spelling difficulties, DD is characterized by a wide range of deficits affecting different linguistic domains. These deficits needs to be seriously considered if we want to have a comprehensive picture of this disorder. Specifically, dyslexics have difficulties in the phonological domain, particularly in activities of phoneme recognition and manipulation (Bishop & Snowling, 2004; Ramus & Szenkovits, 2008; Vellutino et al., 2004; Vender & Melloni, 2021) as well as in the morphological domain. The persistent reading difficulties observed in children with DD may negatively impact on the emotional sphere and social skills of these children and generally lead to an increase rate of school exclusion and dropout (Cremonesi et al., 2017), with important consequences also from a socioeconomic perspective in terms of access to higher education and job opportunities. Developing suitable tools and interventions that support the child in their language development is thus of the utmost importance. Importantly, in fact, both decoding and linguistic abilities can be successfully trained, as shown by a growing number of studies conducted on both children and adults, highlighting the contribution of both phonological and morphological activities in supporting reading development (Galuschka et al., 2014; Bowers et al., 2010; Vender et al., 2022). Phonological awareness, which can be defined as the ability to identify and manipulate sound units (Blachman, 1991) plays indeed a crucial role in literacy acquisition and in developing the child's reading skills, as it drives the automatization of grapheme-phoneme conversion rules (Snowling et al., 2020) and is widely recognized as a strong predictor of reading skills development. More recently, psycholinguistic research has observed how morphological awareness, the ability to identify and manipulate morphemes, also aids reading development, by positively affecting both decoding and text comprehension (Arnbak & Elbro, 2000; Casalis et al., 2004; Kuo & Anderson, 2006; Levesque & Deacon, 2022; Pacheco & Goodwin, 2013). In fact, morphologically complex (i.e., affixed) words are typically read faster and more accurately than simple words matched for length and frequency by both typical and DD readers of any age (Burani et al., 2008; Carlisle & Stone, 2005; Levesque & Deacon, 2022). Despite the attested deficits in both derivational and inflectional domains (Casalis et al., 2004; Vender, 2024; Georgiou et al., 2022), dyslexic and less-skilled readers seem able to resort to their morphological abilities to compensate for their reading difficulties (Burani et al., 2008; Marcolini et al., 2011; Traficante et al., 2011). Intervention studies targeting the development of morphological skills have indeed been reported as particularly effective, leading to improvements in both decoding and comprehension (Bowers et al., 2010; Levesque & Deacon, 2022).

However, there are still significant barriers to accessing intervention, related to factors such as length and expensiveness, and to the difficulty of extending the intervention beyond the clinical context. It has also been observed that to be effective, training should be personalized based on the child's needs, which is often hardly feasible (Catania et al., 2021). To this end, interactive technologies can provide an important asset. In many cases, they have been found to be more effective than traditional interventions in the acquisition of language skills, especially when based on the use of regular devices such as computers, tablets, or smartphones (Crovari et al., 2021). Computerized training programs facilitate the development of activities that have proven particularly effective in automating and speeding up decoding, such as the Reading Acceleration Paradigm, which consists of structured reading exercises in which children are encouraged to read faster than their usual rate (Breznitz, 1997, 2001; Breznitz & Share, 1992). Current technologies also permit the implementation, in an extremely ecological manner, of a range of activities that are traditionally recognized in literature as effective for strengthening both decoding and comprehension. A web-based reading intervention integrating phonological and morphological activities in a technological environment can thus be particularly effected, as shown by a recent study (Vender & Delfitto, 2024) reporting significant gains in reading speed and decoding as well as in phonological skills in adults with dyslexia. Within the Italian intervention framework, a number of digital applications have been developed to support children with SLD. One notable example is EdiTouch[1], a specialized tablet offering several activities for students from primary to secondary school: among others, it includes a text-to-speech eBook reader, a talking calculator, and a talking keyboard that offers real-time spelling feedback

[1] https://www.tabletascuola.net/ (cons. 09.04.2025).

and correction. The Leggimi App[2] automatically applies a dyslexia-friendly font to texts to enhance readability. TurboLettura[3] is a gamified reading app using voice recognition to analyze the child's reading-aloud performance in real time. It provides instant feedback and corrects errors in a game-like progress manner. Finally, RIDInet[4] is a web-based platform that includes customizable apps for reading, writing, math, language, and executive functions. Therapists can monitor the individualized training sessions remotely, integrating activities such as reading short texts with comprehension questions, timed syllable and word reading, and spelling dictation.

2. THE CURRENT STUDY

The aim of the current work is to develop a cutting-edge technological tool providing favorable ecological conditions for enhancing the effectiveness of language and reading training programs for children diagnosed with developmental dyslexia. To do so, we developed a linguistic training program tailored to the linguistic and cognitive profile of each child participant, aimed at specifically addressing their needs. While other platforms, as those mentioned above, already use interactive and multisensory approaches to dyslexia intervention, our tool focuses specifically on improving the child's literacy skills through targeted, tailored linguistic activities aimed at enhancing phonological and morphological competence yielding positive effect of both reading and spelling. For the first time, to our knowledge, it also includes an innovative focus on derivational morphology as in important component for improving decoding. At both levels of linguistic analysis, we offer a range of customized activities designed to strengthen the child's phonological and morphological awareness, which, as shown in the literature, can effectively support the child in the decoding process. The training involves the independent use of a web application (on a computer, tablet or smartphone) for three days a week for a total of ten weeks. Each session lasts approximately 15-20 minutes.

3. METHODOLOGY AND PROPOSED ACTIVITIES

Participants: The training is currently ongoing and involves 30 Italian children diagnosed with DD, aged from 8;1 to 11;10 years (Mean age = 10;1, SD = 1;1, Male participants = 10), recruited through the ULSS Scaligera 9 Verona (Italy). The same number of children with DD will be part of a control group and will therefore not take part in the training program, in order to verify the effectiveness of the intervention. We expect to have the first results of the study comparing the two populations by May 2025.

Design: Before the start of the training, all participants (i.e., both control and experimental groups) are tested in a series of tasks to assess their reading proficiency and linguistic abilities at phonological and morphological levels to gather precise information about their initial reading and linguistic profile. The same tasks will also be administered after the training to verify the presence of improvements related to the intervention.

Reading and linguistic assessment: As for reading skills, we administered the DDE-2 (Sartori et al., 2007) and MorfoLet (Tagliani et al., in preparation), an original test of word and nonword reading to examine the role of morphological analysis in the decoding process. We also tested the children's phonological (Vender et al., 2020; Vender & Delfitto, 2024) and morphological skills. For the latter, we administered a series of novel morphological tests designed for Italian derivational morphology (adapted from Piccinin & Dal Maso, 2023). Participants were also evaluated in their lexical and grammatical competence by means of PPVT (Dunn & Dunn, 1965) and TROG-2 (Bishop, 2009) tasks, as well as in their reading comprehension (Prove MT-3, Pra Baldi et al., 2010).

Training materials: Since both phonological and morphological skills play a crucial role in improving reading and spelling abilities, the training activities we developed aimed at enhancing these two linguistic dimensions. All activities were designed to have an increasing level of difficulty, which can be represented by syllabic complexity, number of syllables or presence of complex orthographic groups in phonological exercises, or by semantic and orthographic transparency of derived words and their frequency in the morphological ones. Participants can proceed to the next level once they achieve 80% accuracy in the task. Otherwise, the level must be repeated. Immediate feedback is provided in all exercises, and if an error is made, the correct solution is shown.

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[2] https://leggimi.app/ (cons. 09/04/2025).

[3] https://onehealthvision.com/app/turbolettura-trattare-dislessia-difficolta-lettura/ (cons. 09/04/2025)

[4] https://www.anastasis.it/ridinet/ (cons. 09/04/2025)

The training starts with the phonological activities until about halfway through the program. The first activity is *Rapid reading*, which involves the modulation of on-screen persistence of given stimuli ranging from 200 to 2000ms. Children are shown a stimulus (syllable, word or nonword) displayed for a limited time and once it disappears, they are asked to rewrite it. The on-screen persistence is tailored to each participant's reading proficiency, as assessed during the preliminary testing phase, and gradually decreases through the levels. In *Pick the correct word*, children are presented with two words and must choose the one spelled correctly. This exercise is also offered in a version with auditory aid. In *Dictation*, participants listen to a stimulus (syllable, word or nonword) and are asked to write it correctly. In *Listen and choose the right match*, children listen to an auditory stimulus (syllable, word or nonword) and must select the correct writing among four options, including phonologically or visually similar competitors. Similarly, in the *Listen, look and choose* task, participants must select the correct writing form upon hearing the stimulus, but they are also aided by the presence of a picture representing the target word (see Figure 1-left panel).

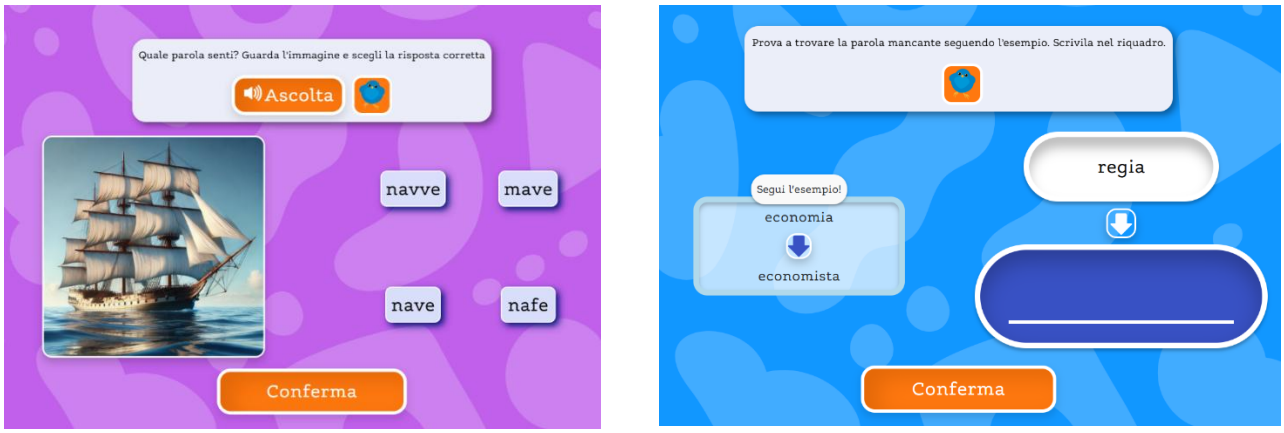

Figure 1. Display screens of two activities: the *Listen and choose the right match* task (left panel) and the *Morphological pattern* task (right panel).

Morphological training is introduced by the 15th session. We decided to focus on 12 high-frequency Italian suffixes (Gaeta & Ricca, 2003): *-ista*, *-tore*, *-mento*, *-zione*, *-aio*, *-eria*, *-aggio*, *-ismo*, *-ità*, *-oso*, *-bile*, and *-ale*. Suffixes are introduced gradually and each time new suffixes are added, they are presented in a short video featuring the character *Ispettore Morfolix*, who explains the meaning of the specific suffix. The first morphological activity resembles the *Rapid reading* task described above. The only difference is in the type of items presented, which in this case are derived words of 4 or 5 syllables. In *Word sort*, children must determine whether a word is simple or derived (e.g., *chitarra* 'guitar' vs. *chitarrista* 'guitarist') and place it into the correct basket. In *Word Building*, children are presented with a series of bases and suffixes and are asked to combine them to form the correct derived word (e.g., *dentista*, 'dentist', composed by the root *dent-* 'tooth' and the agentive suffix '-ista'). In *Word puzzle*, they are asked to identify both simple and derived words and pair them appropriately (e.g., *chitarra-chitarrista*,'guitar – guitarist'; *costruire-costruzione*, 'construct-construction'). In *Morphological pattern*, participants are shown two words belonging to the same semantic family in a base/derived word relationship (e.g., auto-autista, 'car-driver'). Based on the morphological relationship established between these two words, children must complete another two-word set for which only one element is given to form a similar morphological pair (e.g., musica-…, 'music'-…, missing word: musicista 'musician') – see Figure 1-right panel. Finally, in the *Find the Word in the Text* activity, participants are presented with short sentences and asked to identify and write down the derived word found in the text.

4. APPARATUS

To facilitate language training and supply exercises in an engaging way, we have developed DEA (*Dyslexia Exercises Application*). DEA is a web-based application built on a modular architecture, designed to manage and deliver interactive exercises. The platform allows therapists to create and assign training sessions to participants, monitor their progress and support tailored interventions. Participants, instead, can engage in their assigned training sessions through the application.

Training session: All the training sessions are designed to be conducted with the aid of interactive exercises provided through activities. Activities are composed of at least one exercise, and each exercise is divided into several tasks. To create a session, therapists (experimenters, in our study) must name the session, select the exercises that must be executed during the session and specify the corresponding user (see Figure 2). Users can be also added after the creation of the activity. Therefore, the training session is a sequence of exercises, and at the same time exercises are a sequence of tasks.

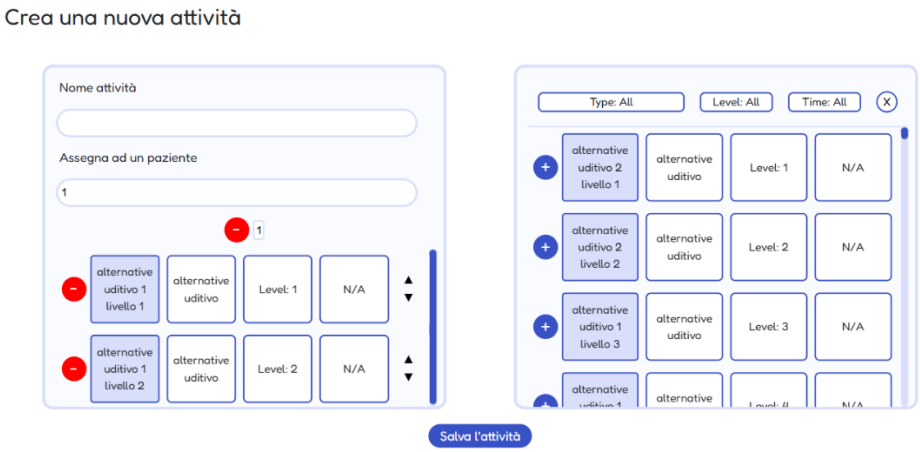

Figure 2: Display screen of the activity creation, here therapists set the activity name, exercises and the assigned users.

User flow: Users log into the application by using their username and password. On the first screen after the login, a page displays all the assigned uncompleted sessions, along with the corresponding completion rate (see Figure 3). Users can start and complete the sessions in any order and can also pause or resume them as needed. Once the user selects a session, the training experience will start. While performing tasks, users can at any time ask for help from the system by clicking on the bird icon, answer the task or quit. If a user asks for help, the system will play an audio that contains information about the task and how to interact with the system to complete it. The session progress is saved at the end of each single task: in this way when a user resumes their session they'll continue from the first uncompleted task. This allows users to break their activities when overwhelmed and rest until they're motivated to resume the session. For each task the system displays the instruction text, its position within the exercise and the exercise's difficulty level (see Figure 4 – right panel).

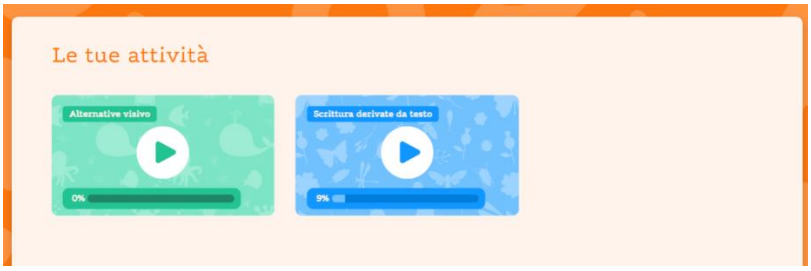

Figure 3: Display screen of the uncompleted activities of the logged user.

To complete an activity, users must complete all the exercises in it, and to complete an exercise the users must answer all the tasks that compose it. When the user answers correctly to a task, the system displays positive visual feedback (see Figure 4 – top left panel) and then moves to the next step. This could be the next task within the same exercise, the next exercise if the current one was completed, or the home screen if all the scheduled exercises have been completed. If the users provide a wrong answer, the system will show negative visual feedback (see Figure 4 – bottom left panel); in some cases, users can repeat a task for a limited number of times (e.g., in the *Word Puzzle* activity), while in others the tasks will not be repeated, and the system will move forward to the next step.

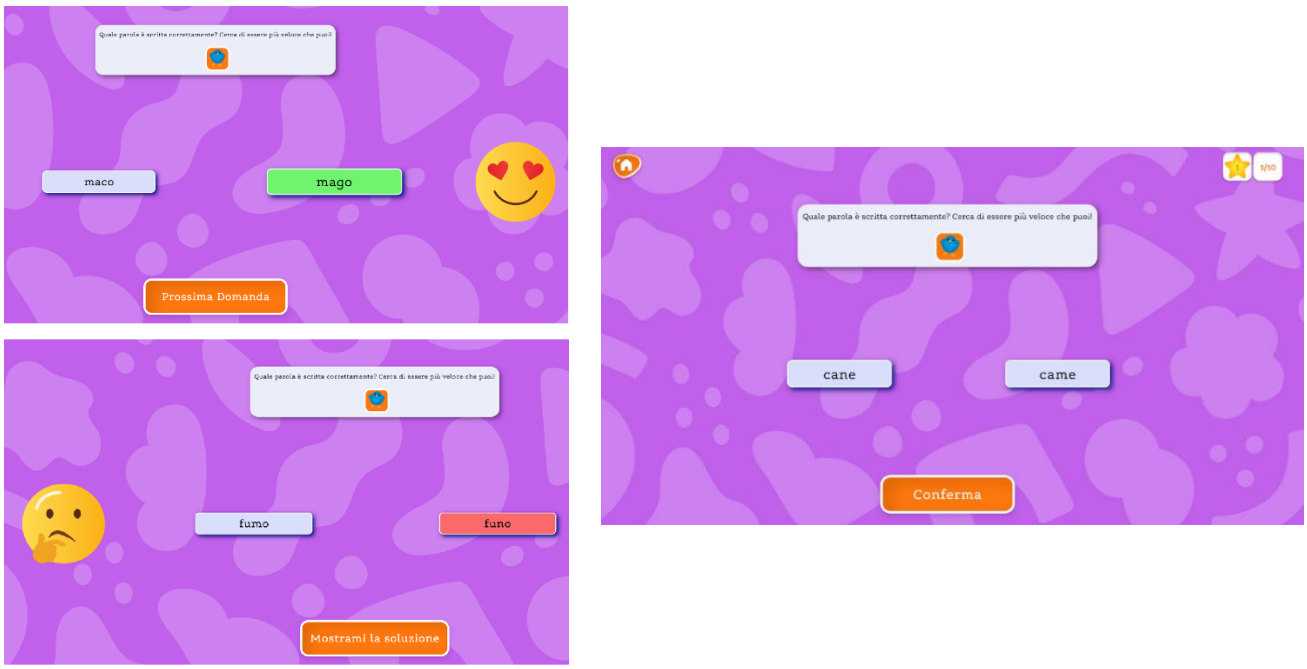

Figure 4: The right panel shows the display screen of a task. The task position and exercise difficulty level are shown at the top-right corner of the page. The help button (Blue Bird) is placed immediately below the instruction text. The left panel shows display screens of visual feedback. The top screen shows negative feedback, the bottom screen shows positive one.

5. CONCLUSION

We presented the design of an experimental study aiming to create an advanced technological tool for the linguistic training of children with DD. Our research has a very high potential social impact as it makes it possible to create technological tools for the improvement of reading difficulties through a web-designed application that is highly ecological for both the user and the therapist, with the scheduling of exercises tailored to the participant's linguistic and cognitive profile. The modular nature of the web application also paves the way for future implementations to other areas of intervention relevant to SLD learners (e.g., dyscalculia) or for adapting exercises to different school grade levels. We are currently collecting data, and the next step will involve analyzing the effectiveness of the training by comparing children's performance on the pre- and post-tests, as well as administering usability surveys of the app to both parents and children.

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