A cura di
CATIA GIACONI E NOEMI DEL BIANCO

E-HAND. EMPOWERING CHILDHOOD HANDWRITING

TRAIETTORIE INCLUSIVE

FrancoAngeli

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COLLANA DIRETTA DA
CATIA GIACONI, NOEMI DEL BIANCO
SIMONE APARECIDA CAPELLINI

La collana "Traiettorie Inclusive" vuole dare voce alle diverse proposte di ricerca che si articolano intorno ai paradigmi dell'inclusione e della personalizzazione, per approfondire i temi relativi alle disabilità, ai Bisogni Educativi Speciali, alle forme di disagio e di devianza. Si ritiene, infatti, che inclusione e personalizzazione reifichino una prospettiva efficace per affrontare la complessa situazione socio-culturale attuale, garantendo un dialogo tra le diversità.
I contesti in cui tale tematica è declinata sono quelli della scuola, dell'università e del mondo del lavoro. Contemporaneamente sono esplorati i vari domini della qualità della vita prendendo in esame anche le problematiche connesse con la vita familiare, con le dinamiche affettive e con il tempo libero. Una particolare attenzione inoltre sarà rivolta alle comunità educative e alle esperienze che stanno tracciando nuove piste nell'ottica dell'inclusione sociale e della qualità della vita.
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La collana si rivolge a tutti i professionisti che, a diversi livelli, si occupano di processi inclusivi e formativi.

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Introduction

by *Noemi Del Bianco, Catia Giaconi, Lucia Borsini, Ilaria D'Angelo, Aldo Caldarelli*

Based on the "E-Hand. Empowering middle childhood Handwriting"[1] project, this work aims to reflect on the theme of Specific Learning Disorders (SpLDs), addressing central issues in the current scientific and pedagogical debate.

In Italy, the growing interest and widespread attention to the protection of the rights of persons with SpLDs have led to a series of measures, culminating in Law 170/2010, which introduced new rules on Specific Learning Disorders and the related "Guidelines for the right to education of pupils with SpLDs" (2011). This legislative intervention has given impetus to information and training initiatives, including national projects, as in the case of the initiative discussed in this volume, which have contributed over time to raising awareness in various areas, from schools to the territory and even to families themselves.

Taking charge of SpLDs requires, in fact, a strong educational and multidisciplinary alliance, where school, professionals, and families collaborate with competence and mutual respect for the educational success of the child.

[1] We acknowledge financial support under the National Recovery and Resilience Plan (NRRP), Mission 4, Component 2, Investment 1.1, Call for tender No. 140 published on 02.02.2022 by the Italian Ministry of University and Research (MUR), funded by the European Union – NextGenerationEU– Project Title "E-Hand. Empowering middle childhood Handwriting" n. 2022AWATR2 – CUP D53D23012830006 - Grant Assignment Decree No. 1060 adopted on 17/07/2023. by the Italian Ministry of University and Research (MUR).

Specifically, the school has a central role in the prevention, early identification, and design of personalised interventions for pupils with SpLDs, through systematic observations and targeted educational actions. People with SpLDs do not have intelligence problems, but experience significant difficulties in reading, writing, and calculating, affecting basic instrumental skills, which are essential for learning and many daily activities.

For these reasons, the educational path of these people can be difficult, especially if the educational context is not adequately prepared to recognize the early signs of SpLDs and to intervene in an appropriate way for prevention.

For example, as we will see in the pages of this volume, the transition from kindergarten to primary school is a crucial phase for developing reading, writing, and numeracy skills; therefore, the early detection of risk signals through screening practices is vital to monitor any difficulties. Timely interventions are essential to prevent the development of the disorder and to promote the positive development of the child. It is essential, however, to distinguish between temporary learning difficulties, which can be overcome with appropriate interventions, and Specific Learning Disorders, which require specialized diagnoses.

Adequate training of teaching staff and educational co-responsibility are crucial to avoid late diagnosis, which could compromise the effectiveness of the intervention and the evolution of the disorder. From the early stages of training, future teachers, educators, and pedagogists must be made aware of the conceptual and operational guidelines relating to SpLDs. These professionals must acquire skills to work in synergy with other specialists involved in the diagnostic process to achieve an integrated approach and adequate care. In addition, it is necessary to orient oneself in a complex landscape, where there are divergent positions on intervening. For this reason, professionals in training must be up-to-date through the most authoritative sources of the scientific community and have practical skills to deal with learning difficulties. Among the most relevant aspects, there is a need for targeted training to identify early risk signals and initiate timely interventions that can prevent the severity of the disorder. The awareness and preparation

of professionals are, in fact, key elements for an effective intervention, which takes into account the specific needs of each person.

Starting from these considerations, the volume puts screening paths at the center of the pedagogical debate with particular attention to writing requirements. This choice is also in line with recent data published by the Ministry of Education and Merit (September 2024), which shows an increase in dysgraphia certifications over the last nine years (from 30,000 in the 2013/2014 school year to 111,000 in the 2022/2023 school year). This trend highlights the urgent need to strengthen prevention/early intervention practices and teacher training. Timely screening in the 5-6 year age group makes it possible to identify writing-related difficulties and their prerequisites, such as fine motor control, visual-motor coordination, and spatial organisation.

For these reasons, the volume opens with a focus on Specific Learning Disorders, to frame the phenomenon as a whole. In the first chapter, an overview of SpLDs allows the reader to appreciate the conceptual boundaries of Disorders, namely dyslexia, dysgraphia, dysorthographia, and dyscalculia, to provide theoretical and operational tools able to recognize difficulties at an early stage and implement targeted interventions.

In the second chapter, however, attention will be paid to the specific dimensions of dysgraphia. As Giaconi and Capellini (2015) point out, addressing the complexity of dysgraphia requires an in-depth knowledge of the physiology of the writing process. Our analysis proposes a conceptual path that starts from identifying the prerequisites and processes involved in writing. Then it analyzes the state of the art on standardized tools and screening protocols to detect predictive signs of dysgraphia.

It is, instead, in the third chapter, that an operational trajectory of how novel technologies based on the concept of adaptive tutoring can be helpful to design innovative training aids to improve writing and intervene at an early stage for possible dysgraphia issues will be shown. In this direction, the recent PRIN 2022 “E-Hand. Empowering middle childhood Handwriting” project is, therefore, a significant example of current research perspectives in this field.

The book concludes with a reflection on inclusive trajectories, highlighting the centrality of continuous and specialist training for teachers, the importance of integrating innovative teaching technologies, and the need for a concrete alliance between school, family, and professionals. The conclusions also underline how an integrated and collaborative approach can guarantee an effective management of Specific Learning Disorders, promoting training processes for all students.

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1. Specific Learning Disorders: state of art and pedagogical implications

by *Catia Giaconi* and *Lucia Borsini*

1. Introduction

Specific Learning Disorders (SpLDs) are an important topic in today's scientific and pedagogical discussions (Berninger & Wolf, 2009; Bara & Gentaz, 2011; Coffin & Gentaz, 2011; James & Engelhardt, 2012; Overvelde & Hulstijn, 2011, Ceccacci *et al.*, 2024). These disorders encompass a diverse range of difficulties that disrupt specific academic skills, such as reading, writing, and math, becoming central to an interdisciplinary debate that includes neuroscience, special education, psychology, and educational sciences. For instance, this chapter aims not only to define the characteristics of SpLDs but also to foster critical reflections on educational implications, intervention strategies, and the significance of prevention. This contribution will explore key conceptual issues related to SpLDs, providing a comprehensive and critical overview of the main topics currently under discussion. It will begin by addressing the definition and classification of these disorders, emphasising the necessity of an integrated and interdisciplinary approach to fully understand them. The complex nature of SpLDs requires an analysis that transcends a personal limit to capture the various ways these disorders manifest in different learning and developmental contexts.

This first chapter aims to serve as a foundation for the entire volume, acting as a bridge to the subsequent chapters. For these

reasons, we start with a general overview and a broad reconstruction of SpLDs. A significant focus will be placed on the normative frameworks and evolving terminology that have shaped the history of studying SpLDs, tracing the journey from early definitions to the latest educational and pedagogical perspectives. In this context, special attention will be given to the importance of prevention, a critical area for educational research and intervention. Investigating its trends and developments emphasises the necessity of adopting early and systematic approaches to identify and address difficulties before they become entrenched, thus promoting harmonious and inclusive growth for every student. It is clear that the prevention of SpLDs does not end with preventing the onset of the disorder but aims to create a broader educational and inclusive context that can foster the full development of each pupil's potential, while reducing the risk of failure and dropping out of school.

In summary, the synergy that is fostered by the adoption of evidence-based tools for the early detection of disorders, combined with the ability to provide timely and targeted educational responses, is the foundation for a truly inclusive school.

Therefore, in light of what has emerged, it should be emphasised that at the basis of effective prevention is the need to promote an inclusive culture which is able to give centrality to the training of educational staff and the active involvement of families. From a pedagogical point of view, the entire prevention framework is structured around two main operational guidelines: teacher training through inclusive educational approaches and the school-family relationship, capable of integrating preventive action with systematic attention to the child's needs (Giaconi & Capellini, 2015).

2. Terminological and regulatory developments

The Consensus Conference (2009, p. 19) identified several key issues that have generated considerable debate within the scientific community regarding Specific Learning Disorders (SpLDs). These issues include, for example, the necessity for clear definitions, a comprehensive understanding of epidemiology and aetiology, and

the establishment of robust diagnostic criteria and evaluation procedures. Additionally, attention must be directed towards detecting early indicators, understanding the developmental trajectories of people with SpLDs, and addressing comorbidities and prognostic outcomes. For these reasons, the Consensus Conference represents the turning point for numerous studies that have addressed, over the years, the topic of SpLDs, revealing a diverse array of perspectives on various related issues, including the interpretation of these Disorders (Cornoldi *et al.*, 2010; Giaconi & Capellini, 2015; Toffalini, Gioffrè & Cornoldi, 2017; Giaconi *et al.*, 2019; Del Bianco & Mason, 2021; Murdaca, 2022; Giaconi *et al.*, 2023; Giaconi *et al.*, 2024). The field of SpLDs is inherently broad and complex and, as we explore this area, we encounter multiple theoretical positions and approaches that only sometimes align with their understanding of the phenomenon or their intervention strategies (Ginieri-Coccossis *et al.*, 2013; Kavkler, KoÅ & Magajna, 2015; Minolin, Meena & Karthikeyan, 2020). Given this heterogeneity and the latest scientific findings, certain conceptual domains and phenomena necessitate further exploration and detailed investigation (Giaconi & Capellini, 2015; Woodcock & Hitches, 2017; Ceccacci *et al.*, 2024).

For these reasons, we consider both the reference terminology, recognised nationally[1] (Giaconi & Capellini, 2015) and internationally (Consensus Conference, 2009), and the legislative references that established a legal framework in Italy to ensure the rights of people with these Disorders.

Starting from a terminological reconstruction, the definition of SpLDs is the cornerstone for understanding the complexities of this phenomenon (Giaconi & Capellini, 2015; Kunhoth *et al.*, 2024). Establishing a shared definition is essential, as uncertainties regarding the criteria for diagnosing and recognising these disorders

[1]The main national regulatory sources on the subject: Law 170 of 2010: "New regulations on specific learning disorders in schools", Guidelines for the right to study of pupils and students with specific learning disorders issued in 2011 by the Ministry of Education, Universities and Research (MIUR), and the 2022 Guidelines: Management of Specific Learning Disorders issued by the National Institute of Health.

hinder the ability to compare research findings and assess their prevalence and impact. SpLDs are not to be confused with general learning difficulties; they refer to disorders that significantly impair specific skill domains – reading, writing and arithmetic – while leaving general intellectual functioning intact. The term 'specific' is central to this classification, highlighting the circumscribed nature of the impairments, which, despite their significant effects, do not compromise overall intellectual abilities. This delineation is supported by the notion of 'discrepancy', which is critical for diagnosis. Discrepancy refers to the gap between an individual's performance in the affected domain (reading, writing, or arithmetic) and their general intellectual abilities, as defined in the 2009 Consensus Conference.

Specifically, SpLDs, which include dyslexia, dysgraphia/dysorthographia and dyscalculia, are lifelong conditions that can significantly affect an individual's ability to function in academic, occupational, and social contexts. Despite their neurobiological origins, these disorders do not indicate reduced intelligence but rather reflect specific neurocognitive differences that persist over time.

Their impact – as we are going to see – underscores the importance of early prevention, targeted interventions, and ongoing support tailored to the evolving needs of people throughout their development into adulthood.

Considering the legislative reform specific to the Italian context, a salient moment in the field of SpLDs is certainly enshrined by the enactment of Law no. 170 of 8 October 2010, 'New regulations on Specific Learning Disorders in schools', and the subsequent Decree 5669 of 12 July 2011, 'Guidelines for the right to study of pupils and students with Specific Learning Disorders'.

Law no. 170/2010 identifies dyslexia, dysgraphia and dyscalculia as Specific Learning Disorders and mandates schools to adopt personalised educational approaches. In this respect, there are several salient passages to be explored in line with the profound motivations behind this discussion. The law, from its very first provisions, recognises SpLDs as primary and specific conditions, not secondary to inadequate cognitive abilities, neurological pathologies, or sensory

disabilities (Art. 1(1)). In particular, SpLDs are distinguished according to specific characteristics that include difficulties in reading accuracy and speed (dyslexia), in graphic production (dysgraphia), in the linguistic processes of transcription (dysorthography) and in the automatisms related to calculation and number management (dyscalculia) (Art. 1(2-5)). The law also specifies that these disorders may occur singly or in combination, highlighting the heterogeneity and complexity of clinical manifestations and individual functioning profiles (Art. 1(6)).

The aims outlined in the law (Art. 2) are clear and articulated: to ensure the right to education in schools of all levels, to promote the scholastic success of students with SpLD, to enhance their individual potential and to foster general emotional and relational well-being. Law no. 170 also aims to guarantee equal opportunities for the development of personal capacities, not only in the school environment, but also in social and professional contexts, thus contributing to the construction of an inclusive future oriented towards the full realisation of each individual's potential (Art. 2(1)(h)).

A further central aspect that is highlighted concerns diagnosis, which is entrusted to the National Health Institute and accredited facilities, with the aim of guaranteeing both a timely and accurate diagnostic process and early educational interventions that can mitigate the impact of the difficulties on school and personal life (Art. 3(1)). In this perspective, the importance of specific and targeted training for teachers at all levels is emphasised in order to equip them with the necessary tools to identify early signs of risk and to adopt appropriate educational and teaching measures (Art. 4). This training should cover the main strategies for recognising risk profiles and implementing timely interventions while promoting close collaboration with families and health professionals. The latter, in fact, are responsible for diagnostic assessment and rehabilitative treatment while actively contributing to the design of customised educational approaches, emphasising an integrated and participative approach (Art. 5).

On a pedagogical level, Law no. 170 represents a fundamental point of reference, highlighting certain educational and didactic

emergencies that require focused and structured action. Prominent among these is the need to promote comprehensive care for students with SpLD, coupled with ongoing training for school and education personnel. The perspective outlined by the law is clearly systemic and longitudinal, as it aims to consider the child or young person with SpLD in their development, both in school contexts and in everyday life, emphasising the need to guarantee the full right to education for all students.

In line with these assumptions, the introduction of the Personalised Educational Plan, regulated by Ministerial Decree no. 5669 of 2011 and the Guidelines[2] annexed thereto, makes it possible to finalise the learning and scholastic success of students with SpLD during primary and secondary school. Article no. 5 of Ministerial Decree no. 5669, of 2011 in fact states: «The school specifically guarantees individualised and personalised educational interventions for pupils and students with SpLD, also through the development of Personalised Educational Plans (PEP), indicating the compensatory tools and dispensatory measures adopted» (Art. 5, Ministerial Decree no. 5669/2011). Note how the conjunction 'also' reiterates the non-compulsory nature of developing Personalised Educational Plans but presupposes the wording of a document that adheres to what is set out in the article itself. This is the reason why there is no standardised model of such a document that is the same for all educational institutions. However, in order to reduce the school's margins of discretion, the Guidelines, published by the Ministry of Education in 2011 and annexed to the reference decree, identify precise characteristics that must be present in each PEP, including the methods, contents and timing for drafting this planning document. In any case, the term PEP is the most widespread and used by schools (Fogarolo, 2013).

The school's collaboration with the family, reiterated in the 2011 Guidelines, is of fundamental importance: «In the preparation of the documentation in question, it is essential to liaise with the family, which can communicate to the school any observations on experiences developed by the student independently or through

[2] "Guidelines for the right to study of pupils and students with Specific Learning Disorders".

extracurricular pathways» (Ministry of Education Guidelines, 2011, p. 8). The PEP thus assumes the function of providing the families with documentation of the planned intervention strategies, thereby strengthening a relationship of sharing a work plan geared towards enhancing the student's educational success.

In summary, numerous ministerial documents (Ministerial Decree of 27.12.2012; Note no. 2563 of 22 November 2013, Ministerial Circular no. 8/2013, Departmental Decree no. 1061 of 15.10.2015, Legislative Decree no. 66/2017, Legislative Decree no. 96/2019) have recognised over time the Personalised Educational Plan (PEP) as the preferred tool for the activation of an individualised and personalised approach that has «the purpose of defining, monitoring and documenting – according to a collegial, co-responsible and participatory elaboration – the most suitable intervention strategies and learning assessment criteria» (Ministerial Circular no. 8/2013, p. 2). From this perspective, the PEP represents the operational document in which didactic-educational planning, programmatic interventions of a didactic-instrumental nature, dispensatory measures and compensatory tools can be included. The main methodological directions of the ministerial documents can be traced back to a vision of the PEP as a shared and participated approach, both inside and outside the school context, and the preferred tool for educational and didactic flexibility, capable of bringing the individualised and customised approach closer to its broader inclusive process.

In light of these definitions and the normative references, it seems appropriate – from our point of view – to move forward with an informed look at the pedagogical emergencies that they call into question, moving towards a critical analysis of the main challenges that professionals and parents are called upon to face during the longitudinal care of persons with SpLDs. Before proceeding in that direction, a brief identification of Specific Learning Disorders follows.

2.1 The reading, writing and calculation Specific Disorder: a brief overview

In this section, we concentrate on conceptual frameworks that are widely accepted by the scientific community, as well as on research trajectories that warrant thorough exploration. The aim is to provide foundational elements for professionals in the educational sector to enhance their understanding of SpLDs and to identify key concepts deserving of investigation in their professional practice (Giaconi & Capellini, 2015).

While not entering into the specific framework and in order to highlight the variety and heterogeneity of individual profiles, the main identifications attributable to dyslexia, dysgraphia, dysorthographia and dyscalculic frameworks will be outlined.

2.1.1. Dyslexia

The Specific Reading Disorder, commonly referred to as dyslexia, significantly affects the instrumental skill of reading, with impairments in reading fluency and correctness, without an impairment in general intellectual functioning (Consensus Conference, 2009, p. 37).

Dyslexia, in fact, is characterised by difficulties in the correct sequence of reading (from left to right, in changing lines) and in decoding skills, which result from a disorder of the phonological component of language. It is also characterised by impairment in language processes, especially in the phonological process of speech and later in the phonological process required for reading (Temple *et al.*, 2000).

A person with dyslexia presents various manifestations, representing a complex syndromic picture of specific, primary symptoms of the disorder, which persist even in the presence of exposure to continuous, highly stimulating and motivating reading exercises. Among the main ones, the literature (Etchepareborda,

2002; Shaywitz, 2006; Capellini, 2009; Giaconi & Capellini, 2015) identifies the following:

- difficulty recognising and analysing the alphabetical signs of a word in the correct sequence;
- disorientation when confronted with graphic signs differently oriented in space (d-b, p-q, p-d, q-b, u-n, a-e, ecc.) and alphabetical signs corresponding to similar sounds;
- omissions of graphemes and syllables;
- omissions of words on the line to be read;
- inversions of graphemes and syllables;
- addition or repetition of syllables;
- difficulty in finding one's way around the line to be read and loss of the line in the action of going to the end of the line;
- invention of words, keeping the first part of the written word;
- poor reading fluency compared to classmates;
- difficulty in retrieving words or phrases to be used for the expression of facts or ideas;
- difficulty understanding speech or reading;
- difficulty understanding the use of grammar in forming sentences;
- difficulty remembering numbers, letter sequence, directions, ecc;
- difficulties in organising and planning tasks to be performed.

In the same vein, investigations have looked into aspects closely related to slowness, the tendency to tire easily, the propensity for low self-esteem and a low sense of self-efficacy (Capellini *et al.*, 2009). In particular, the relationships between poor reading fluency and other components related to reading in the broader sense have also been studied. First of all, a child, tending to 'read well' and decipher the words of a sentence, invests all their energy in this action, therefore, they have no more resources to use for understanding what they are reading.

Secondly, the perception of inadequacy and sense of uncertainty increase over time and the feeling of not being able to read is amplified. This inevitably leads to a tendency to reduce spontaneous reading, to avoid reading the text aloud or to avoid the task itself.

2.1.2 Dysgraphia and dysorthographia

As we will see in detail in the next chapter, the terminologies most commonly used to identify Specific Writing Disorder can be traced back to the terms 'dysgraphias' and 'dysorthographias' (Giaconi & Capellini, 2015; Kunhoth *et al.*, 2024; Giaconi *et al.*, 2024). The plurality refers to a broad correlation of such a Disorder, both in reference to the motor component of the act of writing, i.e. the execution one in terms of legibility, fluidity and accuracy, related to dysgraphia (Capellini & Souza, 2008; Capellini, Coppede & Valle, 2010; Okuda *et al.*, 2011; Kunhoth *et al.*, 2024), and in the merit of the orthographic component, proper to textual production, defined by some as dysorthographia (Fletcher *et al*., 2018; Giaconi & Capellini, 2015).

In the case of dysgraphia the main difficulties are related to an uncertain assumption of the motor sequence underlying the coordination of movements and the organisation of action, poor skills in fine manual dexterity, inadequately acquired lateral dominance or difficulties in eye-hand coordination, as well as difficulties in sequential visual recognition or memorisation (Engel-Yeger, Nagauker-Yanuv & Rosenblum, 2009; Gvion & Friedmann, 2009; Pollock *et al.*, 2008; Lousada *et al.*, 2009; Giaconi *et al.*, 2024). Whereas dysorthographia involves various aspects of language and thinking, which call into question ideas in linguistic representations that need to be organised, stored and, later, retrieved from memory (Zucoloto & Sisto, 2002; Galaburda & Cestinick, 2003; Cervéra-Mérida & Ygual-Fernández, 2006; Manzano *et al.*, 2008; Giaconi, & Capellini, 2015).

There are several characteristics of this syndromic picture. The main ones that Giaconi and Capellini (2015) identify include:

- incorrect handling of the writing instrument;
- alteration of writing size;
- variation of pressure on the sheet (weak or excessive);
- poor organisation in the space of the writing sheet, with a tendency to observe a lack of alignment of the writing with the left margin on pages;
- writing lines with irregular patterns;

- tendency to stick words together and not keep the right space between words (irregular spacing between the letters of a word and between words in a text);
- tendency to rewrite and redo what has already been written, with the presence of elongated links between graphic signs and between words;
- tendency to overlap graphic strokes or leave closed forms open (e.g. ‘o’);
- irregular in shape and size, and not very stable;
- illegible and incomprehensible handwriting;
- substitutions, omissions, inversions of graphemes;
- alterations in word segmentation;
- inversion, transposition and substitution of letters;
- inaccuracies in letter-to-sound conversion;
- alteration of the order of syllables;
- slowness in visual perception;
- slowness in the execution of writing and fatigue.

A person with dysgraphia and/or dysorthographia, by investing all their cognitive and energy resources to improve their handwriting, ends up not having enough residual energy to devote to other fundamental actions such as articulation and organisation of concepts, textual enrichment, revision and self-correction. Such an excessive effort, prolonged over time, generates a sense of inadequacy both in the act of writing and in written production, leading to significant fatigue and general demotivation. All this contributes, on the whole, to progressively reducing the inclination towards writing or avoiding it altogether.

2.1.3. Profiles of dyscalculia

When the Specific Learning Disorder pertains to the specific domain of the ability to calculate, one speaks of dyscalculia. Specifically, it refers to the impairment of written calculation in terms of number manipulation, mental calculation and retrieval of arithmetic facts.

Again, the characteristic feature of the Disorder is specificity, in other words, performance is below what is expected for age in a condition of adequate intellectual functioning, relevant level of schooling and absence of sensory or neuropsychiatric disability profiles. Longitudinal studies conducted by Jordan and Montani (1997) with 7-year-old children with disorders in the calculating process examined up to the age of 9 show how the disorder persists despite the presence of maturity in the calculating cognitive system and the administration of stimulating exercises. We are therefore dealing with a disorder that persists over time, i.e. one that is not characterised by transient difficulties related to the process of acquiring written calculation procedures.

The Consensus Conference (2009) classifies two frameworks of dyscalculia: the first is profound, the second procedural.

Profound dyscalculia is characterised by an impairment in the processing of numerical parts. The most significant errors that can be observed are:

- in the semantic processes of numerical cognition;
- in the immediate recognition of small quantities, hence that process we called, in the section on the physiology of computation, subitising;
- in the breakdown and re-composition of quantities;
- in serialisation and comparison.

Procedural dyscalculia, on the other hand, relates to procedural aspects of the calculation process and is the more frequent form than the one just described. The most frequent errors in this case include:

- in syntactic and lexical processes;
- in reading and writing numbers (e.g. instead of writing 107, the child writes 1007);
- in the positional value of the digits;
- in the ordering and positioning of numbers;
- in recognising the sign of the operation (e.g. performs a '+' addition instead of an '×' multiplication);
- in written calculation procedures;
- in the mental calculation (in terms of applying the procedure and maintaining and retaining it);

- in the remainder and carry-over;
- in the retrieval of arithmetical facts.

With reference to such difficulties, there are numerous studies (Wang *et al.*, 2014; Carey *et al.*, 2016) that highlight how poor performance in mathematics might elicit anxiety about mathematics, especially in children and young people with developmental dyscalculia (Lai *et al.*, 2015; Passolunghi, 2011). Some researchers (Maloney *et al.*, 2011; Passolunghi, 2011) claim that the onset of anxiety about mathematics may be due to difficulties in basic numerical skills, such as numerical cognition, which would lead dyscalculics to develop a negative relationship with mathematics from the earliest years of schooling.

3. Pedagogical challenges: early warning, diagnosis and intervention

Entering into a critical analysis of the main pedagogical challenges involved in caring for people with SpLDs, prevention constitutes a cornerstone of the contemporary pedagogical debate, playing a crucial role in the student's educational success.

This approach takes the form of an articulated set of interventions aimed at reducing the incidence of difficulties and limiting their negative impact on the child's development (Penge, 2010; Capellini & Giaconi, 2015; Giaconi, Taddei, Del Bianco & Capellini, 2018; Isidori & Prosperi, 2019; Capellini *et al.*, 2020; Giaconi *et al.*, 2024).

Specifically, a distinction can be made between primary, secondary and tertiary prevention, depending on the objectives and methods of intervention.

As far as primary prevention is concerned, it focuses on actions to counter the onset of disorders through the strengthening of basic prerequisites, such as language skills, motor coordination and memory capacity. In schools, for example, this approach translates into the implementation of educational activities aimed at promoting the full development of the child's cognitive and relational skills (Penge, 2010; Giaconi & Capellini, 2015).

Secondary prevention, on the other hand, focuses on early detection of signs of risk. In this respect, the adoption of screening tools is effective, through which it is possible to identify children who, as early as the last year of pre-school or the first two years of primary school, manifest difficulties in the development of reading, writing and calculation processes. This type of intervention, which is not limited to detecting individual difficulties but involves the entire class group in inclusive reinforcement approaches, is based on scientifically validated observational protocols. Early identification enables the early activation of targeted educational approaches, preventing difficulties from structuring into established disorders and facilitating more effective functional recovery (Giaconi & Capellini, 2015).

Finally, tertiary prevention targets children who have already manifested the disorder, with the aim of preventing its worsening and reducing the onset of secondary comorbidities. This approach involves targeted interventions, including the use of compensatory tools and the design of customised educational paths aimed at ensuring the person's overall well-being (Giaconi & Capellini, 2015).

In such a framework, the central element of prevention is early diagnosis, i.e. observation protocols aimed at the early identification of groups of children who, as early as the last year of preschool and the first two years of primary school, may present a set of difficulties in the development of the precursors and processes of reading, writing and calculation. Between the end of preschool and the beginning of primary school is, in fact, a crucial moment in the progressive refinement and consolidation of the requirements of reading, writing and calculation. The two most important developmental periods concern precisely the 5 to 6-year-olds (high precocity) and 6 to 7-year-olds (low precocity) ranges, thus confirming the need to detect risk predictors with reference to possible SpLD frameworks already during these 'developmental windows' (Stella & Gallo, 2005; Ianes *et al.*, 2007; Giaconi & Capellini, 2015). It is at this stage that early recognition of signals, such as the failure to develop phonological skills or difficulty in

understanding logical sequences, can prevent an increase in complications.

In this regard, several knots still need to be unravelled in the area of prevention.

Firstly, scientific research attempts to demonstrate the real opportunity to prevent a disorder, i.e. the possibility of early detection of reliable indicators, which occur before the disorder appears. Secondly, the scientific community is seeking to ascertain whether specific work aimed at reducing these risk indices actually leads to a reduction in the likelihood of the occurrence of SpLD.

Let's examine the substance of these two issues.

Indicators or risk factors are identified as «personal and social elements whose presence increases the likelihood that an individual will manifest a given disorder over time» (Penge, 2010, p. 39) and which, therefore, could become central in prevention projects as early as preschool. What needs to be clarified is that the presence of a risk threshold in the context of SpLD is connected with 'an increased likelihood of developing the disorder' (Penge., p. 40) over time and not with an unequivocal identification of people who will definitely have an SpLD condition. The scientific literature (Penge, 2010; Capellini & Giaconi, 2015; Giaconi, Taddei, Del Bianco & Capellini, 2018; Isidori & Prosperi, 2019; Capellini *et al.*, 2020; Kunhoth *et al.*, 2024; Giaconi *et al.*, 2024) attempts to trace, with increasingly accurate longitudinal research and interesting documentation through case studies, the presence of a number of risk factors of a potential SpLD framework. These include (Consensus Conference, 2009, p. 49) important critical signs to be identified at an early stage, such as the possible presence of a family history of the disorder, delays in the acquisition and development of communicative-linguistic, motor-praxic, auditory and visual-spatial skills at pre-school age. The result that emerges is, therefore, that of a plurality of definitions referring to the most likely predictive early signs, a heterogeneity that reflects the diversity of interpretation of the disorders.

As early diagnosis and intervention play a decisive role in the development of the disorder, numerous studies (Baker & Smith, 1999; Morris *et al.*, 2000; Penge, 2010; Giaconi & Capellini, 2013;

Isidori & Prosperi, 2019) have shown how the effectiveness of screening approaches enables the reduction of the extent of SpLD. At the procedural level, however, professional caution is required. A screening process must have several cornerstones to be effective. Prominent among these is the principle of cost-effectiveness, i.e. the protocol must make it possible to observe the SpLD risk group more accurately and with less expenditure of energy and resources. In addition, screening must meet the principle of reliability, i.e. it must use tools that are standardised and validated on a large scale and are based on scientific findings in the field of SpLDs.

Such detection procedures can be designed and conducted by practitioners, but also by trained teachers who, moreover, can make use both of everyday school life for continuous observation over time and of screening as a constant monitoring system. For these reasons, we believe it is of paramount importance to focus not so much on the selection of teams of professionals from outside the school to carry out the screening in the school, but on the training of school staff so that it becomes a shared and stable practice over time.

3.1 The role of professionals in the early warning, diagnosis and empowerment intervention

Closely related to the above-mentioned evidence is a further aspect of pedagogical relevance concerning the careful and accurate planning of training and refresher courses for school staff of all levels, possibly also to be extended to the families concerned. There are various training courses that should be aimed both at knowledge of the law, but also at an in-depth study of the complex framework of SpLDs, of the different procedures for early identification, of the educational-didactic strategies for reinforcement, of the different and possible compensatory tools, of the most appropriate forms of verification and assessment.

The primary objective in supporting the training of professionals is to ensure access to essential elements and areas of consensus that can effectively guide them through this complex field.

Since «SpLDs [...] constitute a complex phenomenon of vast social proportions that has hitherto been little recognised» (Stella & Savelli, 2011, p. 7), such uncertainties and the plurality of viewpoints can occasionally create confusion (Giaconi & Capellini, 2015).

One key aspect that warrants consideration is the tendency to overlook Specific Learning Disorders or broaden their definition to encompass all educational difficulties. In this case, we face a dual challenge: on one hand, the failure to recognise SpLDs promptly can lead to the loss of critical opportunities for intervention; on the other hand, there exists a tendency to confuse Specific Learning Disorders with 'general learning difficulties' (Giaconi & Capellini, 2015, p.14). In this regard, as highlighted by Giaconi and Capellini (2015, p. 14), «those elements highlighted signify critical points from a pedagogical perspective. Firstly, the early identification of difficulties and the implementation of timely habilitative interventions are acknowledged as favourable prognostic factors; this indicates their profound influence on the progression of the disorder. Secondly, it is essential to clearly delineate the conceptual boundary between difficulty and disorder to prevent the misinterpretation of recommendations for clinical practice as indicative of disorders» (Giaconi & Capellini, 2015, p. 14).

This clarification aims to establish a clear distinction for all professionals involved in the educational context, including teachers and educators. It is essential for these professionals to avoid the extremes of either overlooking potential SpLDs by allowing issues to persist unaddressed or assuming that all students facing challenges automatically have an SpLD. Both tendencies can lead to detrimental practices, including a lack of engagement or excessive reliance on diagnostic services, fostering a mindset where difficulties are expected to be resolved on their own or are inaccurately categorised (Giaconi & Capellini, 2015).

Research (Penge, 2010; Capellini & Giaconi, 2015; Giaconi, Taddei, Del Bianco & Capellini, 2018; Isidori & Prosperi, 2019; Capellini *et al.*, 2020; Kunhoth *et al.*, 2024; Giaconi *et al.*, 2024) indicates that learning difficulties can be characterised as general challenges that a student may encounter within the school environment. These difficulties can be transient and may be

effectively addressed through targeted interventions (Dockrell & McShane, 2000; Feder & Majnemer, 2007; Capellini, 2009; Capellini *et al.*, 2009; Ianes, Cisotto & Galvan, 2011; Borean, 2014; Rosenblum & Dror, 2016; Danna *et al.*, 2023; Kunhoth *et al.*, 2024). In contrast, SpLDs pertain to specific impairments that significantly impact a person's ability to adapt in academic, professional, and daily living contexts. SpLDs are recognised for their persistence over time and can be formally diagnosed through a comprehensive assessment process, conducted by professionals.

These discussions highlight the need for further clarification of these critical aspects of the subject in order to provide guidance to various professionals involved in training.

3.1.1 The pedagogical-didactic dimension in the early warning, diagnosis and empowerment intervention

Further reflection that emerges in our discussion concerns the frequently overlooked implications of SpLDs on the development of co-identity and their impact throughout a person's lifespan, from early education to adulthood. This encompasses challenges related to academic failure, increased dropout rates, and negative effects on career progression.

Therefore, as a corollary, another major dimension emerges that is closely related to the entire school career of the student with SpLDs: the didactic-pedagogical dimension of planning and personalisation. Inevitably, this issue invokes the very core of didactic action in terms of constructing pathways for the whole class, within which there are different paths for personalisation, in this case, for students with SpLD. This dimension represents, in our opinion, one of the greatest challenges in this regard, i.e. to experiment together, in everyday life and within the different educational proposals, possible approaches for students with SpLD.

In the regulatory framework, while noting the need to activate dispensatory and compensatory measures, the emphasis, in our opinion rightly, is placed on the «use of individualised and personalised teaching, with effective and flexible forms of school

work that also take into account the specific characteristics of the subjects, such as bilingualism, adopting an appropriate methodology and educational strategy» (Law no. 170/2010, Art. 5(2)(b)).

The sustainability of the approaches, however, is the indicator that could make any assumption fail. In fact, it is a matter of experimenting with approaches that are potentially manageable, throughout the school year, by both teachers and students. It is therefore necessary to design customised teaching plans to be used within class groups. The pedagogical-didactical emergency manifests itself in the urgent need to support forms of experimentation aimed at inclusive education. The focus, therefore, becomes polarised not on a generic plan of dispensatory measures and compensatory tools, but on the feasible construction of an integrated system of methodologies and didactic mediators, on the one hand, responsive to the educational needs of children/young people with SpLD, and on the other, context-sensitive and inclusive for all pupils.

We are talking about dispensatory measures[3] related to dysfunctional instrumental skills (e.g. dispensation of reading aloud, copying on the blackboard) and compensatory tools[4] (such as the use

[3] «Dispensatory measures are interventions that allow a student with SpLD not to perform certain tasks that, due to the disorder, are particularly difficult and do not contribute to functional learning. Available studies on the subject recommend estimating the extent to which the specific difficulty penalises them in comparison with peers and calibrating additional time or reduction of work material accordingly while taking into account the student's performance indexes. In the absence of more precise indices, an additional 30% appears to be a reasonable additional time» (Ministry of Education Guidelines, 2011, p. 7). By exempting the pupil from certain tasks, the pupil avoids a feeling of frustration and low self-efficacy, allowing them to manifest their competences (Zappaterra, 2012). The quality of interventions depends on the possibility of experimenting with strategies that allow people to develop forms of control and self-regulation over their own performance (Giaconi & Capellini, 2015).

[4] Compensatory tools are «didactic and technological instruments that replace or facilitate the required performance of the impaired skill» (Guidelines, MIUR 2011, p. 7). In fact, they compensate for the student's specific difficulty by allowing them to use their energy for more effective learning. These tools, which can be low-tech or high-tech, should be evaluated on the basis of the personal needs of each student. Moreover, they do not simplify the execution of the task from a cognitive point of view and do not put the student who uses them in a privileged position with respect to others, but rather allow the student to achieve

of didactic and technological tools) that allow support for performance based on the impaired skill.

It should be pointed out that dispensatory measures relate to dispensing tasks that, given the SpLD, could subject the person to excessive effort with the result of losing the very content of the activity and exposing them to unnecessary frustration. These measures are also carefully designed and timed according to the subject's profile, the structural and temporal characteristics of the activity and the methodologies proposed by the teacher. The line to be pursued, also for homework, is to support ways of working that favour the quality of thinking and not the mechanical execution of a large number of exercises. We reiterate, in fact, that the quality of interventions hinges on the possibility of experimenting with effective strategies and developing forms of control and self-regulation of one's own performance. Change in learning, therefore, is not achieved by repeating numerous exercises, for example, by rewriting sentences several times where the correct spelling rules have not been used.

Whereas compensatory tools are facilitators, with reference to the performance framework that the SpLD condition makes particularly difficult. These tools must be proportional to the length and complexity of the proposed activities. With regard to the use of technological compensatory tools, the initiation and preparation process that can lead the student to the knowledge of the tool and its autonomous use should not be underestimated. Think, for example, of the use of computers. This precludes working on memorising the keyboard in such a way that the subject achieves an adequate writing speed to be able to concentrate not so much on finding letters on the computer keyboard, but on the cognitive task.

In conclusion, the line to be pursued and favoured is, in our opinion, that of choosing the system of devices that is most functional to the participation and autonomy of the individual with SpLD. The choices must be weighed with reference to the specific nature of the profile and the precise space-time dimension in which

the same goals as their classmates, thanks to a customised approach that sees the introduction of such tools aimed at overcoming difficulties due to the disorder (Zappaterra, 2012).

the person lives, in order to achieve real educational gains in terms of future autonomy and skills development, also with reference to the use of compensatory tools and different ways of approaching study which are useful for educational success.

3.1.1.1 Evidence of inclusive teaching for empowerment intervention

From the above considerations, it seems useful to outline some of the main teaching strategies for implementing learning/enhancement pathways in sections and classes where students with SpLD are included.

As mentioned in the preceding paragraphs, school learning is based on a number of key dimensions (e.g. visual and auditory perception, visual-verbal association, phonological memory and awareness, eye-hand coordination), the development of which can be carefully monitored and consequently enhanced already during pre-school age. Enhancement interventions based on these elements have been extensively researched and validated (Cornoldi, 2007; Angeli *et al.*, 2011; Hulme & Snowling, 2011; Coggi & Ricchiardi, 2014; Kaldenberg *et al.*, 2015; d'Alonzo, 2017; Nepi, 2017; Isidori & Prosperi, 2019), in order to highlight the strategies that teachers can implement in the classroom with a view to applying inclusive teaching.

Specifically, several studies (Kaldenberg *et al.*, 2015; Isidori & Prosperi, 2019) identify a series of exercises considered useful for this developmental group which can be taken into consideration according to the type of strategy to be implemented.

These include exercises useful for visual discrimination, aimed at developing attention, perceptual analysis and executive control. In this regard, exercises in the areas of pairing, reiteration, repetition, coding, semantic organisation, seriation, perceptual highlighting, spatial orientation, etc. can be implemented. For example, recognising and differentiating graphemes from other graphic signs on the basis of their different spatial orientation and shape, without being able to name them; completing simple figures; distinguishing

the figure from the background, discriminating what is larger and what is smaller, and being able to find the differences between similar drawings.

As far as auditory perception is concerned, which enables the perception and differentiation of linguistic sounds belonging to one's own language, teachers can also implement a series of useful exercises for the identification of the minimal components of language. For example, certain rhythms can be associated with larger or smaller images depending on whether they are faster or shorter, or stronger or weaker rhythms. Or specific work can be done on sequential auditory memory and auditory function, perhaps through the ordering of sequences or recognition of a part of a text in the course of the story.

The teacher can also contribute to the facial-auditory integration with the aim of implementing the correspondence between image and sound, in order to facilitate the retrieval of linguistic labels from the verbal lexicon to correctly associate graphemes with phonemes and subsequently name words correctly (Tretti *et al.*, 2002; Grabe & Stoller, 2002). In this regard, exercises in which figures, objects, and symbols must be named and recognised correctly (e.g. puzzles with letters and alphabets) appear useful.

In this age group, phonological memory, which is necessary to train short-term memory to maintain a correct phonological sequence, and metaphonological skills, which enable the recognition and processing of the phonological characteristics of words (Cornoldi, 2007; d'Alonzo, 2017; Neria & Pellegrini, 2017), can also be the subject of specific training. As far as phonological memory is concerned, exercises that allow the identification of individual phonemes that will later be converted into graphemes (during writing) in order to merge them into words (functional for reading) appear useful. Exercises in syllabic metaphonology can be proposed that will allow, with entry into school, better mapping of spelling and better reading. Exercises can focus on the recognition of vowels, flat syllables, complex syllables, spelling digrams/trigrams, closed syllables (Isidori & Prosperi, 2019). With reference to metaphonological skills (or phonological awareness), teachers can implement all those exercises that call into question the ability to

fuse, i.e. to distinguish a word after hearing its phonemes or syllables separately, and the ability to segment, i.e. to break down a word into its constituent sounds (syllables before and phonemes after), without having access to the written code. Examples include: syllable segmentation (e.g. clapping according to how many syllables are in the words); syllable blending (e.g. If I say po-me-gra-na-te what word did I say?); initial syllable identification (e.g. a boatload of words starting with ...WO has arrived); rhyme completion (e.g. rain, rain go away, come again another DAY); word chain identification that allows the identification of words starting with the same syllabic component (e.g. boAt...ATlantIC...ICeland...).

Even with regard to the early years of primary school, didactic research has made clear the importance of certain steps that should be made explicit and taken care of in the learning-teaching processes. From the very beginning of the didactic proposal, studies (Stella & Gallo, 2005; Grabe & Stoller, 2002; Berninger & Woolf, 2009; Giaconi, 2013b; Giaconi & Capellini, 2013; 2015; D'Alonzo, 2017; Giaconi *et al.*, 2024) affirm the importance of constructing the lesson in such a way as to lead the student with SpLD to a high degree of both awareness of the learning work they have to undertake, and of control, choice and manipulation of the material to be learned and of the procedures. In this case, recalling a metacognitive approach, as highlighted in previous studies (Giaconi, 2013a; Giaconi & Capellini, 2013), teachers are advised – especially in the presence of a new topic – to proceed with some useful information before starting the lesson: define the field of work (what will be covered in the lesson or assignment); provide indications of the aims and expected competences; estimate the difficulty of the task (highlighting particularly complex concepts); define the operational modes that will be activated during the lesson (e.g. 'In the first part of the lesson we will do this... then we will do some exercises'); give indications of sources (reference texts and relevant pages, photocopies, etc.); make connections with previously covered topics (either in a sense of continuity or divergence/criticality); and be explicit about the assessment methods. In this regard, it is of considerable importance that the teacher, during the lesson, alternates the oral explanation with moments of graphical punctuation of the

key concepts covered, providing an effective graphic organiser. In the explanations, therefore, it becomes relevant for the learning of students with SpLD to either use 'visible' concrete examples 'close to the children's experience', or to guide them to find real or 'absurd' 'mental images' by following so-called visual learning techniques. Of equal importance is the flexibility and variety of sources that the teacher makes available. Therefore, it becomes important for teachers to offer, in addition to textual sources, other sources that the pupil could consult at home (such as films/documentaries, research on the topic via the Internet).

In line with these reflections are the investigations into cognitive styles and teaching styles (Cornoldi, 1999; Giaconi, 2004; Cornoldi *et al.*, 2020). In fact, there is a tendency of style incongruity between teaching (didactic styles) and learning (cognitive styles), which constitutes a key to the very core of the theoretical and experiential problem of didactics. Taking different subjectivities into account calls for reflection on cognitive and learning styles, on individual differences, on respect, on acceptance, on valuing the person in their uniqueness, and suggests not expecting students to learn everything and always in the same way according to a methodological standard established a priori.

The scientific literature (Sternberg, 2003; Giaconi, 2004) emphasises the importance of the so-called 'personal equation' effect, which sheds light on how often teachers' explanations and the guidance they provide in order to acquire a study method reflect their beliefs and previous school experiences. The 'personal equation', in fact, emphasises that the teacher sometimes tends to think that pupils are, in the way they think and study, very similar to them. It seems, therefore, evident that the teacher must conduct careful reflection in this respect as awareness of this natural condition can lead to the enhancement of flexible and inclusive teaching. The teacher's beliefs, i.e. the representations through which they think about their work and which they have developed since attending school as a student, are, therefore, beliefs that should not be underestimated by virtue of their impact on the way they conduct their profession (Giaconi & Capellini, 2013; 2015).

In the vastness of the subject we are dealing with, these are just a few of the strategic approaches that can help us to have an extra key to understanding the complexity of the relationship and teaching-learning processes that are substantiated from the school context to permeate that of the non-school context.

3.2 The importance of school-family partnerships in early warning, diagnosis and intervention

As mentioned above and also reiterated by the 2011 Guidelines, a fundamental aspect for both the prevention and the subsequent treatment of SpLDs is the active and continuous collaboration that must be established between schools and families as a pivotal element for the success of the student's educational pathway.

Prevention cannot and should not be confined exclusively to the school environment; on the contrary, it implies close cooperation with families who are called upon to become an integral part of the educational process, actively contributing to the early identification of signs of difficulty and the implementation of intervention strategies (Isidori, 2017; Ianes & Cramerotti, 2013).

It is essential that teachers develop effective modes of communication based on transparency and mutual respect. For example, during the phase of early detection of risk signs, it is essential that teachers be able to explain clearly and without alarm the difficulties encountered in a way that is objective and understandable to parents. At the same time, it is necessary to avoid amplifying the problem or drawing premature conclusions that could generate unhelpful anxiety in families. The dialogue between teacher and parent should, therefore, be geared towards raising awareness without alarming, and promoting an awareness that prompts early, albeit reasoned, intervention.

Once the prevention phase, which includes awareness-raising activities, training and early identification of risk signs, is over, it is the responsibility of teachers, adequately trained, to carefully monitor pupils' progress and report any persistent difficulties. Such difficulties, which may manifest themselves in the acquisition and

development of instrumental skills in reading, writing and calculation, may, in fact, persist despite the implementation of targeted interventions. It is important, therefore, that parents be informed about the child's specificities and also guided and supported in understanding the next steps to be taken, such as designing specific interventions that may include, for example, the use of compensatory tools or individualised support. The effectiveness of such collaboration also depends on the ability to establish a support network involving other professionals, such as neuropsychiatrists, speech therapists and educationalists. The creation of a multidisciplinary support network makes it possible to address the dynamics in a synergetic manner, ensuring that the solutions adopted are coordinated and integrated, with the aim of fostering the child's development.

Thus, the awareness process that must be established inevitably presupposes forms of collaboration that allow for an ecological vision of the interventions, which is essential to ensure the effective management of a shared approach that can promote the student's educational success throughout their school career.

From these insights, our attention is focused on the direction of a specific in-depth study on one of the SpLDs, namely dysgraphia. If not adequately recognised and addressed, dysgraphia can adversely affect an individual's education and overall well-being. Therefore, it is crucial to reflect on the most effective intervention strategies and preventive practices, which will be the central themes of the next chapter.

4. To summarise

Specific Learning Disorders (SpLD) are a major topic in pedagogical and didactic research (Cornoldi, 1999; Giaconi, 2004; Cornoldi *et al.*, 2020). These Specific Disorders, including dyslexia, dysgraphia, dysorthographia and dyscalculia, affect specific school skills without affecting general intellectual functioning.

The definition and classification of SpLDs has been the subject of in-depth scientific and regulatory research, culminating in important

references such as the 2009 Consensus Conference and Law no. 170/2010. The latter enshrined the right of students with SpLD to customised education, introducing compensatory and dispensatory measures, as well as support tools such as the Personalised Educational Plan (PEP). The legislation has had a significant impact on school practice, promoting inclusive teaching strategies aimed at the educational success of all students.

A fundamental aspect in the management of SpLD is prevention, articulated at three levels: primary, aimed at enhancing learning prerequisites; secondary, focused on early detection of risk signs; and tertiary, aimed at supporting students already certified, reducing the risk of comorbidity and learning discomfort.

In this context, the role of teachers is crucial in adopting effective teaching strategies and in dialogue with families and professionals to ensure comprehensive support for the student's educational success (Giaconi & Capellini, 2015). For these reasons, teacher training plays a key role in building an inclusive learning environment. It is essential to provide theoretical and operational tools to recognise difficulties at an early stage and implement targeted interventions. Personalised teaching, combined with the use of compensatory tools and the promotion of flexible methodologies, makes it possible to respond to the specific needs of each student, fostering more effective learning and reducing the risk of scholastic failure.

Finally, collaboration between schools and families is an indispensable element for the educational success of students with SpLD. A constructive dialogue between teachers and parents makes it possible to share strategies and support approaches, improving the quality of implemented training (Giaconi & Capellini, 2015). In short, it is through the synergy between training, prevention and personalisation of interventions that it is possible to build a school that can be truly inclusive.

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2. Dysgraphia: lines of research and perspectives for prevention and pedagogical intervention

by *Lucia Borsini*

1. Introduction

As already noted in the introduction to this volume, in this work our attention will be directed to the investigation of the Specific Learning Disorder of Dysgraphia, as a «complex skill that develops over time and depends on several components» (Borean, 2014, p. 128), resulting as a multidimensional competence to which executive and cognitive functions that inter-relate and influence each other are attached (Zoia & Biancotto, 2014).

In line with the relevant literature (Ianes, Cisotto & Galvan, 2011; Borean, 2014), in this chapter we will see how competence in writing depends on the joint and integrated development of various kinaesthetic, visual-perceptual, spatial, motor, movement planning and proprioceptive awareness skills that enable controlled and fluid manipulation. The integrated pattern of coordinated movements required during the task of writing, in addition to being subject to visual monitoring and sensory-motor feedback (Tseng & Chow, 2000) involves the exercise of both fine motor skills (Capellini, Giaconi & Germano, 2017) and gross motor skills related to postural control (Abd El-Dayem, Salem & El-Hadidy, 2015). These are skills that are the prerequisites for reproducing letterforms in their respective sizes and proportions, arranging them in a serial order according to specific positions on a writing surface (Rosenblum & Dror, 2016), and respecting a linear orientation and overall spatial location.

In addition to a general overview of the phenomenon, our focus of investigation also moves towards possible risk predictors of dysgraphia. These reflections are grounded in research that emphasises that the last year of preschool is the most favourable period for activating processes aimed at identifying such indicators (Mazzoncini *et al.*, 1996). If at the age of four the learning processes of the act of writing are still in an emerging phase of development, one can observe in the performance «transient and spontaneously recoverable characteristics» (Tretti, Terreni & Corcella, 2002, p. 18) that «at five it is rather characterised as a more stable condition and usually less spontaneously compensable by the child» (Tretti, Terreni & Corcella, 2002, p. 18). From these considerations, we will finally come to an examination of what instruments the literature proposes for the detection of the disorder from the last year of preschool.

2. Analysis on writing

In general, the performance of handwriting is «a complex perceptual-motor skill involving a combination of visual-motor coordination skills, motor planning, cognitive and perceptual skills, as well as tactile and kinaesthetic sensitivity [...]. Motor and perceptual components related to the act of writing may include fine motor control (hand manipulation, bilateral integration and motor planning), visual-motor integration, visual perception, kinaesthesia, sensory modalities and sustained attention» (Feder & Majnemer, 2007, p. 313).

Specifically, analysis of writing is considered on three levels:

- as a graphomotor gesture, aimed at the production of letters;
- as the orthographic component, aimed at transforming sounds into letters according to precise rules of a reference writing system;
- as text production, involving cognitive and meta-cognitive skills.

According to research (Angelini, 2016; 2020; Zoia, Biancotto & Girelli, 2023), the act of writing combines inscription and progression, two groups of movements essential for writing.

Inscription, performed mainly by the fingers, is responsible for the drawing of the letters, while progression allows the drawing to develop to the right, integrating hand, forearm and shoulder movements. Coordination between inscription and progression requires neuro-motor maturation and the harmonious development of muscle tone.

In order to facilitate the motor act, there is a natural process that begins in the central nervous system to coordinate and integrate the motor function; thus, it is in the anterior region of the brain that programming, organisation and execution of movement take place. Other cerebral units also participate in the process of motor action by sending messages, controlling force and agility, providing visual, tactile and auditory feedback, allowing movement to achieve increasingly functional adjustments (Kolb & Whishaw, 2002; Giaconi & Capellini, 2015). Specifically, it is in the frontal area that there is initially a movement intention, a programming that is then processed in the pre-frontal cortex. Subsequently, this information passes into the pre-motor area, which lies between the pre-frontal lobe and the motor area and is responsible for organising the motor sequence. Finally, the information is projected into the primary motor area, which sends impulses (through the medulla) to the muscles in order to execute the planned movement. This process is also controlled and regulated by many other structures that control force and speed and give constant feedback to the movement (Kolb & Whishaw, 2002).

Fine motor coordination follows the sequence of natural development; however, some dysfunctions can be observed in some cases. Difficulties in motor coordination relate to the execution of the graphical stroke and graphomotor pathways, components that affect the pupil's performance both with reference to the "quantity" of learning in the classroom and with repercussions on motivation and self-esteem (Trevisan, Coppede & Capellini, 2008; Chung *et al.*, 2020), affecting the entire school success (Gargot *et al.*, 2020). As a consequence, high levels of scholastic performance anxiety can

occur, often leading to the avoidance of written assignments, culminating in a vicious cycle of fewer and fewer opportunities for writing training, eventually leading to school rejection (Danna *et al.*, 2016).

Being the result of multiple functions, writing is, therefore, one of the most difficult skills to learn (Trevisan, Coppede & Capellini, 2008; Vidarte, Ezquerro & Giráldez, 2009), which according to Capellini *et al.* (Capellini *et al.*, 2007; Giaconi *et al.*, 2013; Giaconi & Capellini, 2015), follows specific evolutionary stages, illustrated in the table below (Tab. 1).

Tab. 1 - Evolutionary stages of writing (Giaconi & Capellini, 2015, p. 36)

STEP	OBSERVABLE BEHAVIOUR
1st	Scribbles (unintentional scribbling). Use of colours with different pressures (12 to 24 months).
2nd	Intentional scribbling with the appearance of circular strokes. Palmar grasp. Scribbles and describes the scribbles. Performs vertical strokes by imitating (24 to 35 months).
3rd	Round shapes. Draws with precarious and unorganised forms. Makes crosses by imitation and unclosed circles. Human figure as a 'tadpole' (3 to 4 years old).
4th	Drawing. Draws a logical set. Draws a closed circle. Human figure with head, body and limbs (4 to 5 years old).
5th	More structured drawings. Draws geometric shapes with angles (rectangles and others). Colours more realistically. More detailed human figure. Writes their name on the drawing (5 to 6 years old).
6th	After the age of 6, they structure the details of the human figure even more. They memorise the format and representation of letters and syllables.

In addition to the graphomotor component, the motor-praxis aspect, commonly referred to as calligraphy, also plays a role in handwriting. Good tracing, from the point of view of execution, therefore requires fine motor control, visual-motor integration, motor programming, good proprioception and finger awareness, as well as adequate visual perception and sustained attention.

Specifically, as Giaconi and Capellini (2015) explain, the Italian writing system is characterised by orthographic transparency, i.e., the regularity whereby each phoneme corresponds to a single grapheme and vice versa (Mousinho & Correa, 2009). Given that Italian possesses a complex morphological structure, sensitivity to linguistic morphology is crucial for developing orthographic knowledge (Mota, Anníbal & Lima, 2008; Queiroga, Lins & Pereira, 2006). Word encoding, in the alphabetic writing system, can be explained by the "Dual-Path" process, which means that writing can be produced through a process involving a direct phonological pathway or through a direct visual process, which includes the representation of known words, stored by the visual input (lexical pathway)[1]. Writing through the phonological pathway depends on the use of knowledge of the conversion rules between grapheme and phoneme, which enable the construction of the word's spelling. Thus, a phonological code is created that is intended to be identified by the auditory word recognition system, releasing the lexical meaning. Writing through the lexical pathway is based on "visual" access, which is formed by the recognition of a word and its memorisation, with the retrieval of its meaning, directly addressing the lexical aspect. Words with different levels of alphabetic regularity can be written using this approach (Pinheiro & Rothe-Neves, 2001; Pinheiro, 2006).

[1] According to the studies of Uta Frith (1985), the basic instrumentality of writing, but also of reading, is characterised by a developmental pathway marked by four stages: starting with the logographic stage, followed by the alphabetic and orthographic stages, and finally reaching the lexical stage. In practice, children, from a very early age, are exposed to writing, of which they are only able to grasp its "visual form". At school age, one learns the phoneme-grapheme correspondence (a phonological approach) and then memorises recurring orthographic forms, to be retrieved more and more quickly and thus approach the lexical stage (direct approach) in which a direct retrieval of the orthographic form takes place, abandoning the phonological grapheme correspondence.

According to Manzano, Sanz and Chocano (2008), orthographic activity begins with the selection of the meaning and concept that one wants to write, mainly by resorting to one's own semantic system. Afterwards, it is the syntactic structure that will determine which type of word will occupy which position in the sentence and, only then, will the two pathways (phonological, lexical/orthographic) come into action, which will allow the word to be written. The first is the mechanism for selecting graphemes and the type of character that will be used (e.g. upper case, lower case, bold or other). The second concerns the purely motor aspects in charge of performing the movements corresponding to each grapheme. In this way, the writer uses the phonological pathway to write non-words and infrequent or unknown words, while using the lexical pathway to compose words that are part of the graphemic or orthographic repertoire (Ellis & Young, 1988; Ellis, 1995; Pinheiro & Rothe-Neves, 2001; Pinheiro, 2006; Manzano *et al.*, 2008). A number of scholars (Apel, Wolter & Masterson, 2006; Berninger *et al.*, 2010; Fletcher *et al.*, 2018; Apel, Henbest & Masterson, 2019) reiterate that both phonological and orthographic processes are important for learning to write. Specifically, it is observed that the letter norms of more frequent new words are learnt more easily, just as phonological norms that recur more frequently in words are related to letters more quickly.

Fletcher, Lyons, Fuchs and Barnes (2018) also point to the role of metaphonological skills in promoting spelling competence. Writing within an alphabetic system requires, according to the authors, learning to encode words, which is why metaphonological skills are also needed for understanding alphabetic principles.

Therefore, on the basis of studies in the field (Trevisan *et al.*, 2008; Vidarte *et al.*, 2009; Coppede, Okuda & Capellini, 2012; Capellini, Coppede & Valle, 2010; Pagliarini *et al.*, 2020), sensory, perceptual and fine-motor coordination alterations may be directly responsible for impairments in written expression, i.e. for the framework of dysgraphia as a Specific Learning Disorder.

Finally, the act of writing involves cognitive and meta-cognitive skills necessary for the composition of texts (conception, planning, transformation and revision). In particular, Hayes and Flower (1980)

propose a distinction into three fundamental phases that characterise the entire writing process for the composition of a text.

The first phase is planning, which is the project phase prior to the actual writing. During this phase, you organise ideas, decide what information to include in the text and plan the overall structure of the work. Planning is therefore a crucial phase in which the person chooses and organises their ideas in a coherent manner, taking into account the reader's needs and communicative objectives.

The second phase, transcription, is where the text begins to take concrete form. In this phase, previously planned ideas and information are translated into words, sentences and paragraphs. Transcription is not only a mechanical act of writing, but also a moment in which we decide how to express the content correctly, choosing the right words, the appropriate syntax and the most appropriate tone. This phase requires a good command of the written language and constant attention to the form and content of the text.

Finally, transformation and revision is the phase in which the writer retraces their steps to improve the text already written. This moment of reflection allows one to correct mistakes, reorganise ideas and refine language. Revision can cover various aspects of the text, such as consistency and clarity of ideas, grammar, spelling and punctuation. During revision, the person engages in metacognitive reflection on their work, assessing whether the ideas are expressed clearly and effectively and whether the text meets the objectives set.

The planning, transcription and revision phases are, therefore, interconnected and mutually influence each other, creating a continuous cycle that allows the text to be progressively improved and a satisfactory and coherent end result to be achieved. The act of writing is therefore not merely an act of production, but a process that requires continuous cognitive and metacognitive involvement.

In summary, Pratelli (2022) reminds us that the basic processes for learning to write can be identified in visual-motor perception and integration, spatial-temporal organisation and integration, knowledge and representation of the body layout, right/left orientation, motor coordination, lateral dominance, memory and attention. Writing, therefore, is regarded as a complex human activity that simultaneously involves perceptual and motor components

(programming and execution of motor action), and cognitive and metacognitive processes (Bara & Gentaz, 2011; Overvelde & Hulstijn, 2011).

3. Dysgraphia and dysorthographia

As noted, the acquisition of the components useful for the performance of the act of writing are instrumental in achieving good competence in this area. Formally, the acquisition of handwriting begins at the age of five (preschool) and requires about ten years of practice to reach a level of almost complete automation (Hamstra-Bletz, de Bie, & den Brinker, 1987; Blöte & Hamstra-Bletz, 1991; Charles, Soppelsa, & Albaret, 2003; Ziviani & Wallen, 2006; Chartrel & Vinter, 2008; Accardo, Genna, & Borean, 2013). During this period, handwriting initially evolves at a qualitative level (from the first to fifth years of primary school) (Charles *et al.*, 2003; Accardo *et al.*, 2013), and then reaches increasingly higher levels of speed (from the fourth year onwards) (Sassoon, Nimmo-Smith, & Wing, 1989; Maeland & Karlsdottir, 1991). For example, pressure on the writing instrument regularises over time, moving from excessive application to smoother and more uniform control (Olivaux, 2014; Angelini, 2016; 2020). However, despite constant exposure to the practice, 5% to 10% of children never reach a sufficient level of handwriting automation (Smits-Engelsman, Niemeijer, & van Galen, 2001; Charles *et al.*, 2003), going on to identify what the relevant scientific literature (APA, 2013; Giaconi & Capellini, 2015) recognises under the internationally recognised term of Dysgraphia.

Specific Writing Disorder designates the alteration of handwriting, i.e. the inability to copy or realise the sequence of letters in common words (Giaconi & Capellini, 2015). According to the American Psychiatric Association (APA) (2013), written expression disorder consists of writing skills below the level expected for chronological age, intelligence and schooling. This disorder specifically concerns the motor component of the writing act, i.e. the executing component in terms of legibility, fluency and

accuracy (Capellini, Coppede & Valle, 2010; Okuda *et al.*, 2011; Kunhoth *et al.*, 2024).

Studies agree that the activities in which pupils with dysgraphia have the most difficulty are those based on movements with a tridimensional grip, modulation of force and object pressure, and synchronisation of movements (Engel-Yeger, Nagauker-Yanuv & Rosenblum, 2009; Gvion & Friedmann, 2009; Pollock *et al.*, 2008; Lousada *et al.*, 2009). All this requires a high degree of motor coordination, which is fundamental to acquiring handwriting, along with the neuropsychological integrity necessary to organise the information required to perform actions characterised by fine motor skills (Giaconi & Capellini, 2015).

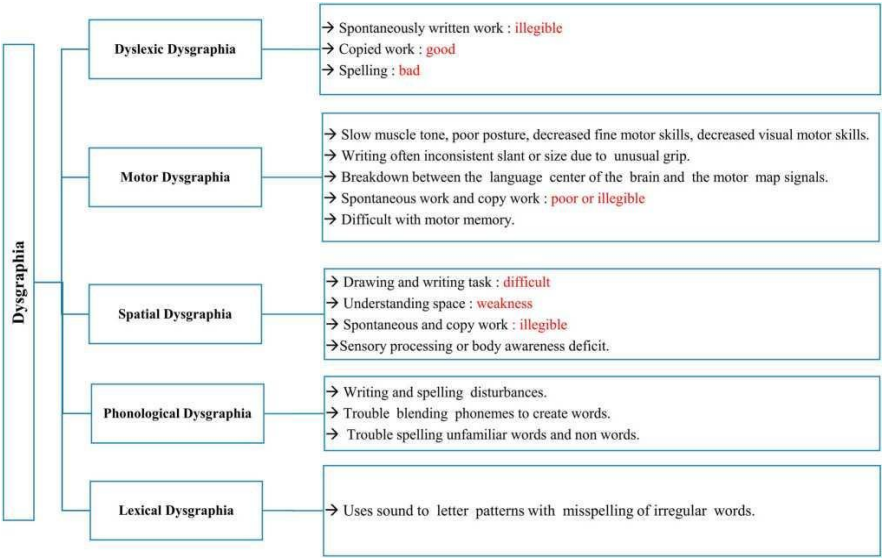
Among the earliest distinctions to be found in the literature is the one made by Lofiego (1995), who distinguishes dysgraphia into ideomotor dysgraphia and ideographic dysgraphia.

Ideomotor dysgraphia represents a dysfunction in the planning and processing of graphic actions. In this case, the person has an obvious difficulty in organising the directional movements in writing. It is also characterised by frequent falls and stumbles (e.g. objects easily fall from the hands, there is difficulty dressing, tying shoes, frequent bumping into people and objects).

Ideographic dysgraphia, on the other hand, represents a specific handwriting difficulty when the child forgets graphic images and has difficulty writing letters. It is characterised by a lack of coordination of movements, the presence of erasures, altered letter direction, errors in letter proportions, specular and upside-down writing of letters and numbers (e.g. 6 instead of 9), a faint and weak stroke, and difficulty in copying from an example to a notebook (from the vertical to the horizontal plane).

Among the most recent dysgraphical distinctions, however, is the one made by Kunhoth and *et al.* (2024), who summarise in the table below (Tab. 2) the basic categorisation of dysgraphia based on the related symptoms. Among the main ones, the authors state that there are forms of “Dyslexic Dysgraphia”, “Motor Dysgraphia”, “Spatial Dysgraphia”, “Phonological Dysgraphia”, and “Lexical Dysgraphia”.

Tab. 2 - Types of dysgraphia identified by Kunhoth et al. (2024, p. 708).



More generally, the manifestations that are observed concern the very quality of the graphic line, which becomes illegible. In this perspective, a close relationship emerges between executive writing difficulties and other aspects of written production, such as spelling and text composition. For example, slowness in writing can lead to a loss of the logical thread of what is being written, causing an increase in spelling errors. Similarly, slowness in the act of writing negatively affects the ability to express one's thoughts in writing, with consequent repercussions on the quality and content of the text produced. In fact, the attention of the person with dysgraphia is mainly focused on the need to "write well" and to maintain a pleasant handwriting, which is considered the most problematic and visible aspect.

As a result, it is difficult to focus on other essential elements of writing, such as spelling accuracy and content coherence. Similarly, hesitations in the spelling of certain words and general insecurity in writing performance tend to further slow down performance and often lead to compensatory strategies, such as progressively reducing the size of the writing until it becomes incomprehensible (Fig.1, for example, "the impressionist").

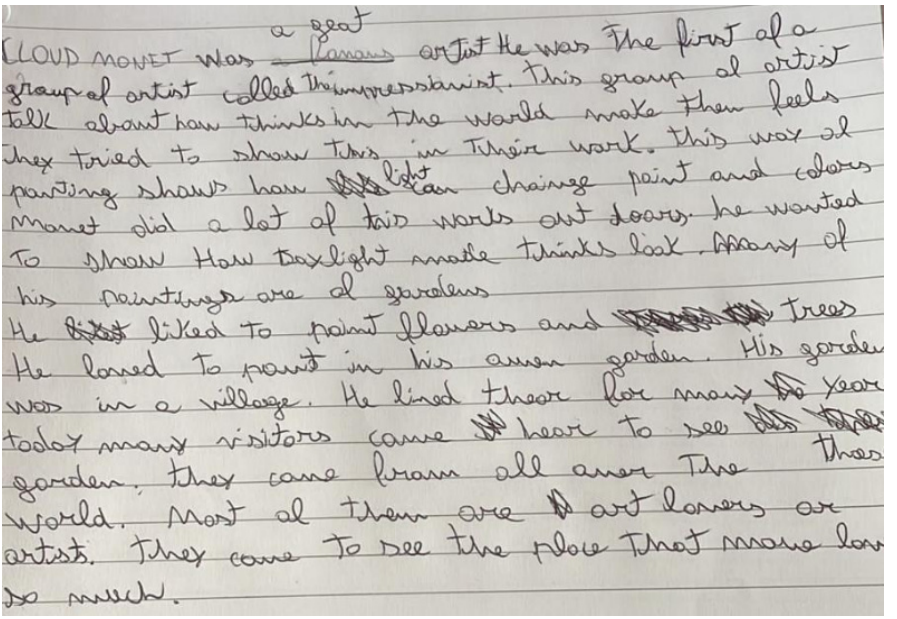


Figure 1 - Example of dysgraphical handwriting (with hesitation of the graphic stroke and tendency to shrink) - student in first year of secondary school

In Fig. 2, on the other hand, it is interesting to note a very frequent aspect in dysgraphical handwriting: the alternation of the written character. In this case, words written in capital letters and words written in italics can be observed in the text. In the example, it can be seen that the handwriting of a boy in his third year of secondary school shows several alterations. The margins are not aligned, especially the one on the right. On the whole, it is possible to observe from the very first sentence the presence of broken links between letters and a tendency to retouch and change letters.

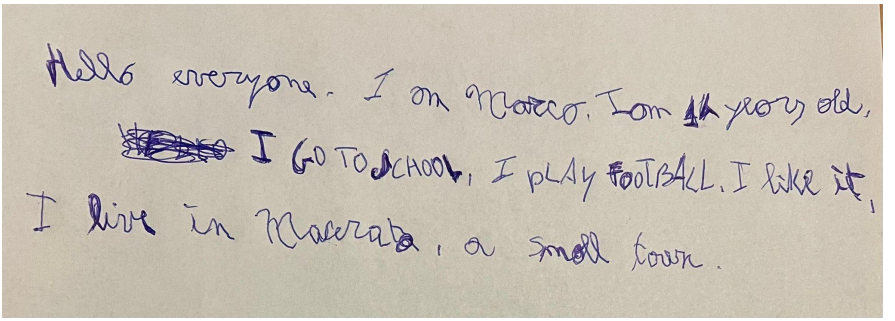


Figure 2 - Example of dysgraphical handwriting (with alterations in the written character)

When the compromised aspect does not concern handwriting, but rather the component of writing related to correctness, also in terms of spelling and syntactic rules, we speak of dysorthographia. The American Psychiatric Association (2013) defines Specific Writing Disorder, also known as dysorthographia, as an impairment in the planning of the written language, which causes disturbances in the learning of spelling and grammar, regardless of the individual's intellectual functioning and schooling according to their age.

The understanding of difficulties associated with written expression still faces obstacles, as there is no shared definition, nor a single standard for specific problems involving spelling, handwriting and text production (Fletcher *et al.*, 2018; Giaconi & Capellini, 2015). This relates to the specificities of orthography that concern the letter production component (handwriting), the textual production that involves various aspects of language and thought, i.e., translating ideas into linguistic representations that must be organised, memorised and, later, retrieved from memory. Dysorthographia, therefore, comprises writing rules that deviate from the conventionally established orthographic rules that govern a given language. Several authors (Zucoloto & Sisto, 2002; Galaburda & Cestinick, 2003; Cervéra-Mérida & Ygual-Fernández, 2006; Manzano *et al.*, 2008; Giaconi, & Capellini, 2015) are unanimous in stating that in the case of pupils with dysorthographia, errors such as substitutions, omissions, inversions of graphemes, alterations in word segmentation, inversion, transposition and substitution of letters,

inaccuracies in letter-sound conversion, alterations in the order of syllables and slowness in visual perception can generally be presented.

The major dysorthographic manifestations in dysorthographic students in the Italian context concern, for example, the tendency to omit doubles, accents, confusion between similar phonemes, the inversion of pairs of opposite phonemes, and the omission of the intermediate consonant and the vowel in intermediate position.

In the example below (Fig. 3), the handwriting of a student in his fourth year of primary school who presents some dysorthographic traits is depicted. In general, in the text, it can be seen that the words are mostly stuck together, which can be traced back to non-phonological errors that refer to incorrect visual representation. It is also possible to note the tendency to omit doubles, on the first line the word “batute” was written without the double “t”, an error that is repeated in the last word of the text. Also in the third line, one can see “tocava” instead of “toccava”, missing the double letter “c”. As far as accents are concerned, it is noticeable that in the seventh line the word “perché” has no accent. Regarding the confusion between similar phonemes, it is noted that the phoneme “sg” was confused with “sc”, in fact, the word “sgridavano” was spelled “scridavano” (fifth line), while the phoneme “qu” was confused with “cu”, visible

The specific traits of dysgraphia and dysorthographia are, therefore, analysed by means of specific, standardised tests that make it possible to verify both the executive aspect, i.e. the realisation of the graphic line, and the orthographic aspect. With reference to the first aspect, the parameters assessed concern both fluency, which must be “-2 standard deviations” from the mean, and the quality of the graphic line. In the second, the criterion considered concerns correctness, in terms of the number of errors. In this case, the statistically significant reference indicator concerns a value at or below the 5th percentile (Consensus Conference, 2009, p. 65).

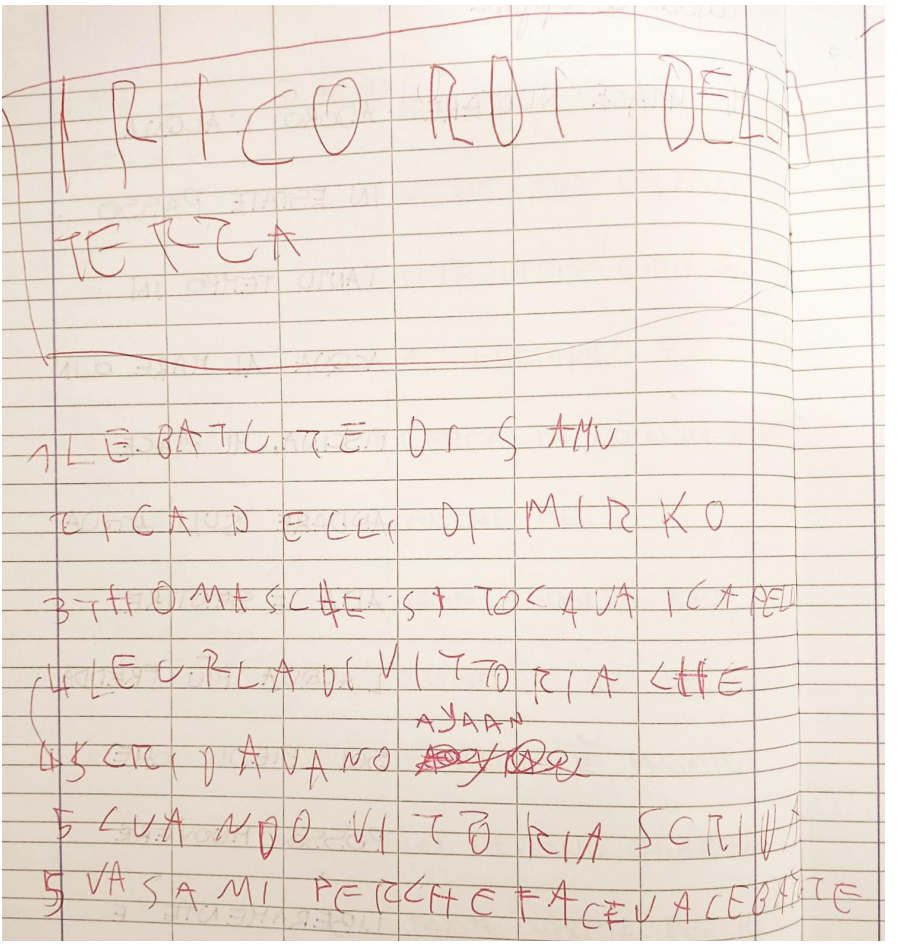


Figure 3 - Example of dysorthographical handwriting (with absence of doubles and accents and confusion between similar phonemes) - student in fourth year of primary school

It should be noted, however, that before proceeding with specific assessments, it would be advisable for both parents and teachers to observe the main alarm bells:

- problems in everyday and school activities requiring fine motor functions, such as buttoning an apron, tying shoes, zipping, drawing with the use of squares, cutting;

- difficulty in writing letters, syllables or words (qualitatively altered strokes, distortion of character shapes, replacement of curves by angles, inadequate separation of characters, irregularity of space between words);
- difficulty in aligning the written line and margins;
- difficult graphic space management;
- difficulty in balancing speed with legibility and accuracy (legible characters and slow writing, illegible characters and fast writing);
- difficulties at school in subjects that require organised writing on the page (pacing, dictation and revision).

After an initial observation, it is possible to proceed with more detailed evaluations that can provide quantitative and qualitative data, which are essential for the design of effective intervention programmes.

4. Knowing how to do prevention: the state of the art of first level assessment tools

As emerged from our reconstruction, an uncertain assumption of the motor scheme underlying the coordination of movements and the organisation of action, poor skills in fine manual dexterity, inadequately acquired lateral dominance or difficulties in oculo-manual coordination, as well as difficulties in recognition or sequential visual memorisation, can have repercussions in activities closely related to writing as early as the last year of preschool. Difficulties in these areas can manifest themselves, for example, in slowness and discontinuity of the graphic gesture, in difficult management of direction and space on the sheet, as well as in weak or excessive pressure exerted on the sheet, to the point of precluding the acquisition of the writing process.

It is, therefore, crucial to identify the components of writing performance «as a means of targeting effective intervention strategies» (Feder & Majnemer, 2007, p. 313). Risk indicators are, therefore, identified as «personal and social elements whose presence

increases the likelihood that an individual will manifest a given disorder over time» (Penge, 2010, p. 39) and which, therefore, could become central in approaches to prevention.

Starting from these considerations, our attention is directed towards reconstructing the state of the art with reference to the tools that have emerged in the national literature that specifically address screening protocols on writing requirements, focusing on the developmental window between ages 5 and 6 (Maniscalsco *et al.*, 2015; Giaconi and Capellini, 2015; Ceccacci *et al.*, 2024).

As analysed in previous works (Giaconi *et al.*, 2024), three databases (Pubmed, Google Scholar, IEEE Xplore) were cross-referenced for the analysis of the reference literature. The thematic keywords used (handwriting test, kindergarten/preschool screening, learning disorders, learning difficulties, dysgraphia test) were used to identify scientific articles from 2000 to the present, tracing them within the titles, keywords and abstracts, in order to identify studies related to our field of research. The timeframe indicated coincides with the technological introduction and diffusion of digital technology, chosen in order to capture the possible impetus given to the definition of the tools under investigation.

From the analysis carried out (Giaconi *et al.*, 2024), the main tools in the literature are as follows:

- The Observational Questionnaire for the Early Identification of Learning Difficulties (IPDA – identificazione precoce delle difficoltà di apprendimento) is an instrument developed by Terreni *et al.* (2002) with the aim of monitoring and identifying writing difficulties, including dysgraphia, at an early stage. This tool is based on guided observation by means of a questionnaire, supported by a series of diagnostic tests that allow various aspects of writing to be investigated. Among the tests included are the PRCR-2, which measures abilities such as visual and auditory discrimination, phonetic memory, phonetic fusion and segmentation, visual-verbal association, and rapid naming (RAN). Other tests include verbal completion and closure, memory span, and the VMI visual-motor coordination test. The predictive indicators investigated through the IPDA cover several areas that were

deemed crucial for the early identification of dysgraphia. These include aspects such as general coordination and fine motor skills, visual-motor and oculo-manual coordination, and spatial orientation. Cognitive skills related to visual and auditory discrimination, auditory/verbal working memory, phonemic fusion, and visual-verbal association are also analysed. In addition, rapid lexical access and anticipation skills are investigated. These indicators are used to detect writing-related difficulties at an early stage, thus providing an opportunity for early and targeted intervention.

- The SR 4-5 Test (School Readiness 4-5 years), developed by Zanetti and Miazza in 2003, is an instrument used to assess the basic skills needed in the transition from preschool to primary school. The test comprises a series of exams aimed at identifying the linguistic, phonological, psychomotor and symbolisation skills required for effective school preparation. Among the tests included are object naming, phoneme and syllable discrimination, and consonant doubling. Phonological similarities, reproduction of articulatory difficulties, and localisation in space are also investigated. Further tests assess praxis (motor movements), lateralisation, and body schema. Other tests concern oculomotor coordination and general coordination, which are crucial indicators for the psychomotor readiness of preschool age children. The test also includes the recognition of graphemes and numbers, which are important for the development of reading and writing. The key indicators that are explored through this tool mainly concern language ability, phonological ability, psychomotor development, and symbolisation, all of which are fundamental skills for success in learning school subjects from the early years of primary school.
- CMF. Assessment of metaphonological skills, developed by Marotta *et al.* (2008), is a tool specifically designed to assess phonological skills in children, with a focus on metaphonological skills, i.e. those skills that allow them to reflect on and consciously manipulate language sounds. The

tests included in the CMF explore different phonological skills fundamental to learning to read and write. The main CMF tests include phonemic segmentation and synthesis tasks, in which the child has to separate or join sounds within a word. Sound classification and manipulation skills are also assessed, such as recognising the initial sound of a word, and recognising the final sound or syllable (as in rhyming). In addition, the test includes the discrimination of words that differ by only one acoustic trait, as in the case of minimal pairs (words that differ by only one sound, e.g. "pail" and "hail"). Other exercises concern phonemic segmentation, phonemic synthesis, and deletion of the initial or final syllable of a word. The production of words beginning with a certain phoneme, and the inversion of the initial sound in word pairs (e.g. through spoonerism activities) are also examined. The main indicators of competence that the CMF explores include general phonological competence, with a focus on global phonological awareness (the ability to recognise sounds within a word) and analytical awareness (the ability to manipulate sounds individually), skills that are crucial for the development of basic language competence.

- The PAC-SI – Test of Cognitive Skills for Preschool (Prove di Abilità Cognitive per la Scuola dell'Infanzia), developed by Scalisi and colleagues (2009), is an instrument designed to assess basic cognitive skills in preschool children, with a specific focus on phonological, memory and visual-spatial skills. PAC-SI tests are designed to measure various cognitive aspects that are crucial for the development of future school competences. Among the tests included in the PAC-SI are figurative rhyme tasks, which assess the ability to recognise and produce similar sounds within words, and working memory tests, in which the child is asked to recall and manipulate information during the task. The test also includes automated rapid naming exercises, which measure the speed with which the child can name objects, colours or numbers. The 2-symbol search is a test that assesses the ability to quickly identify certain symbols in a set of items. In

addition, the PAC-SI includes syllable fusion and syllable segmentation tests, activities that are fundamental to the development of phonological awareness, as well as digit span and naming tests that measure the ability to remember number sequences and to name objects or images. Other key indicators that the PAC-SI explores include visual-spatial short-term memory, which assesses the ability to retain and manipulate information related to visual spaces and shapes, and object sequence search, which measures the ability to organise and recognise visual orders and sequences. The core competencies that the PAC-SI aims to measure include phonological awareness, short-term and working memory, rapid naming, and visuospatial skills, all of which are fundamental skills for learning to read, write, and manage information in space and time.

- SPEED - Screening Preschool Age Developmental Dyslexia (Screening Prescolare Età Evolutiva Dislessia), developed by Savelli *et al.* in 2013, is a tool used to assess early skills that may predict the presence of reading and writing difficulties, such as dyslexia, in preschool age children. The tests included in SPEED are designed to measure various phonological and letter recognition skills, which are early indicators of difficulties in learning to read. The main SPEED tests include letter recognition, letter naming and letter writing, all of which are crucial activities for the development of reading and writing skills. These tests are aimed at assessing phonological competence, which is the ability to recognise and manipulate speech sounds. In addition, the test explores rapid naming, which measures the speed with which a child can name letters, an important indicator for reading fluency. Another important aspect assessed by SPEED is the recognition of graphemes and letters, which is essential for the development of reading and writing, as it enables children to associate sounds with letters and construct words. In general, the main skills investigated by the instrument include phonological competence, rapid naming and recognition of graphemes and letters, all skills that form the basis for

learning to read and which, if impaired, may be indicative of difficulties such as dyslexia.

- Hand to Form – Graphical Test of Constructive Practice, developed by Ambrosini *et al.* in 2022, is an instrument designed to assess children's graphomotor skills, with a specific focus on the skills needed for correct and well-organised writing. The test aims to investigate various aspects of writing and motor skills related to the formation of graphic signs, which are fundamental to the development of writing skills. The tests in this evaluation mainly focus on aspects such as shape, size and spatial organisation, which are crucial in determining the clarity and legibility of the graphic line. In addition, the motor quality in the writing process is assessed, which includes the ability to perform fluid and precise movements with the hand motion. The tests also include the evaluation of conjunctions, which concern the ability to join lines correctly, and of reference lines, which are essential to ensure that the line is well positioned in space. The ability to draw or not close forms correctly is also an aspect monitored during the test. In terms of specific skills, the test focuses on general spatial organisation, which implies the ability to correctly handle the arrangement of letters or signs on the sheet. Also analysed is stroke reliability, i.e. the ability to execute continuous and regular lines, and graphomotor organisation, which assesses how the child coordinates hand movement during the writing process. In summary, Hand to Form explores various aspects of handwriting and graphomotor skills, with a focus on motor precision, spatial management and stroke quality, all fundamental skills for the development of fluid, legible and well-structured handwriting.

In summary, each tool is distinguished by methodological peculiarities and areas of application, contributing significantly to the understanding and early detection of the characteristics of dysgraphia. A comparative reflection reveals how each of them

responds to specific needs, while offering a number of limitations to be carefully considered.

The IPDA, for example, represents a broad and multidimensional tool, capable of providing an overview of writing-related skills. Thanks to its integrated diagnostic framework, it can identify early difficulties in a variety of areas, from visual-motor coordination to phonetic memory.

However, the complexity of its tests requires significant administration time and specific skills on the part of operators, factors that may limit its use in less structured contexts. Similarly, the PAC-SI offers an in-depth, multidimensional assessment, investigating visuospatial skills, working memory and phonological awareness. Again, the richness of the evidence implies greater management complexity, which could be a practical obstacle in some situations. The SR 4-5 Test is characterised by a more general approach, geared towards assessing children's school readiness. With its focus on psychomotor, language and symbolic skills, this tool is particularly useful in the transition between preschool and primary school. However, its holistic nature makes it less specific for the diagnosis of dysgraphia, as it is designed to investigate a broader set of skills necessary for academic success. The CMF, on the other hand, stands out for its focus on phonological and metaphonological skills, with particular emphasis on sound awareness and sound manipulation. Its results, ranging from phonemic segmentation to syllable manipulation, make a crucial contribution to understanding the phonological basis of writing. In this case, however, the exclusive focus on these aspects limits the test's ability to investigate motor or visuospatial dimensions, which are central to the diagnosis of dysgraphia. More specific tools, such as SPEED and "Hand to Form", offer targeted perspectives on key competences. SPEED, designed for the early detection of reading and writing difficulties, focuses on phonological and letter recognition skills. Its concise and focused structure make it particularly effective for rapid administration, even if it does not investigate graphomotor skills. In contrast, "Hand to Form" focuses specifically on the latter, assessing stroke precision, spatial organisation and fluidity of movement. This instrument is one of the most relevant choices for a targeted

diagnosis of dysgraphia, although it may require supplementation with other tests to cover cognitive or phonological dimensions.

In conclusion, the analysis of the instruments highlights the need for a considered choice based on the diagnostic objectives, the age of the child and the available resources. Integrating several instruments may be the most effective strategy to achieve a comprehensive assessment, thus ensuring timely and customised interventions to prevent or mitigate writing difficulties as early as preschool.

5. New research perspectives: school prevention and technological innovation

In the light of the above considerations and by virtue of a reflection adhering to the current context we are experiencing, it seems appropriate to focus our attention on new opportunities and innovative screening approaches that allow deepening frontiers of investigation for educational and didactic research (Pagliarini *et al.*, 2017; Mekyska *et al.*, 2017).

Specifically, the aid of digital technologies, which allow for automated analyses, enable researchers to examine not only the final, static results of handwriting, but also the dynamics of graphomotor movement, capturing details imperceptible to the human eye that prove crucial for the analysis of handwriting predictive factors (Asselborn *et al.*, 2018; Kunhoth *et al.*, 2022; Danna *et al.*, 2023).

As highlighted in the literature (Kunhoth *et al.*, 2022; Danna *et al.*, 2023), numerous methodologies have been developed or are being refined in this field. In general, automated approaches adopt two main ways of collecting data.

The first approach involves offline data collection, where the person is asked to write or copy words and sentences on paper or tablet, allowing for subsequent analysis. The second method, on the other hand, concerns the real-time detection of writing dynamics, including parameters such as the trajectory of the instrument, writing speed and pressure exerted. Such data provide valuable information for the automated identification of dysgraphia and for the enhancement of skills using dedicated artificial intelligence systems.

Among the many operational proposals developed so far, those of Galaz *et al.* (2020), Devillaine *et al.* (2021) and Dui *et al.* (2020; 2022) are particularly suitable for the age group we are interested in. These approaches are based on graphomotor tasks or drawings, thus avoiding the need for children to have already established writing skills, a condition that is often a limitation in automated assessments. While acknowledging that writing and drawing are distinct activities (Harrington *et al.*, 2007), studies based on the analysis of data from drawings (Mekyska *et al.*, 2017; Galli *et al.*, 2019) suggest that dysgraphia may also influence drawing patterns in children. In this sense, Galaz *et al.* (2020) and Devillaine *et al.* (2021) propose tests consisting of the reproduction of different shapes on a graphics tablet.

In the work of Galaz *et al.* (2020), later expanded by Mekyska *et al.* (2023), a protocol with seven graphic tasks is introduced. The first involves the reproduction of an Archimedes spiral about fifteen centimetres high, followed by a reduced version of the same. Subsequent exercises include upper and lower loops, a zig-zag line, arches and, finally, a combined task that integrates the previous elements. These exercises are designed to cover, from a graphomotor point of view, all the essential components of the letters of the Latin alphabet, requiring skills that a child should usually acquire before entering primary school.

Devillaine *et al.* (2021) propose a protocol analysing six groups of drawings, aimed at assessing visual perception and visuomotor integration. Graphomotor tests fall into two types: highlighting tasks and copying tasks. In the former, the child has to trace precisely along a pre-determined grey path, trying not to lift the pen. In the latter, however, they must faithfully reproduce the drawings shown. A specific task, called The Loops, is closer to the act of writing and is particularly useful for detecting and assessing levels of dysgraphia (Lopez *et al.*, 2021; Lopez *et al.*, 2023).

In the Italian panorama, a proposal that enhances the use of digital technologies is that put forward by Dui *et al.* (2020; 2022), which consists of an interactive application designed for graphomotor exercises. The App acquires data useful for analysing motor rhythm, i.e. constancy in the execution of movements (Mather, 2003; Ben-

Pazi *et al.*, 2007). Aspects relevant to the analysis of rhythm are formalised through principles such as isochrony, homothety and the balance between speed and accuracy of movement. Based on these theoretical references, Play Draw Write was developed, a tablet App designed to identify potential indicators of dysgraphia in pre-literacy age. The protocol, lasting about fifteen minutes, proposes playful activities such as copying symbols and simple geometric shapes, such as circles, triangles and squares.

The aim of this device is twofold: to facilitate early screening and to enable longitudinal monitoring, using accessible technology and a playful approach that encourages children's involvement.

It is within this theoretical and methodological framework that the experimental study we will present in the following chapters, called "E-Hand. Empowering middle childhood handwriting". The main objective of this research is to develop specific, inexpensive, rapid, reliable and easily applicable screening systems and procedures in school settings. Special attention is paid to the early detection of graphomotor difficulties in order to promote appropriate and inclusive educational interventions.

6. To summarise

Dysgraphia is a Specific Learning Disorder that impairs the quality of the act of writing, affecting legibility, fluency and accuracy of handwriting (Angelini, 2016; 2020; Zoia, Biancotto & Girelli, 2023). Writing is a multidimensional competence involving motor, perceptual, visual-spatial and cognitive skills, requiring the coordination of several executive and sensory-motor functions. Scientific studies (Accardo, Genna, & Borean, 2013; Giaconi & Capellini, 2015) show that the maturation of these skills follows a specific developmental path, the development of which can be monitored from childhood onwards in order to identify possible difficulties at an early stage.

The analysis of writing can be conducted on three levels: the graphomotor gesture, the orthographic component and textual production. The acquisition of writing skills depends on the

coordination between inscription (movements of the fingers to form the letters) and progression (movements of the hand and arm to advance on the paper). Fine motor control, visuomotor integration and motor planning play a key role in this process.

Dysgraphia manifests itself with difficulties in the spatial organisation of the text, the regulation of pressure on the writing instrument and the fluidity of the graphic line. Several classifications distinguish dysgraphia into subtypes, such as ideomotor dysgraphia, which concerns the difficulty in motor coordination of the graphic gesture, and ideographic dysgraphia, which impairs the retrieval of graphic images of letters (Hamstra-Bletz, de Bie, & den Brinker, 1987; Blöte & Hamstra-Bletz, 1991; Charles, Soppelsa, & Albaret, 2003; Ziviani & Wallen, 2006; Chartrel & Vinter, 2008; Accardo, Genna, & Borean, 2013). Recent research (Kunhoth *et al.*, 2024) has also identified other types, such as dyslexic dysgraphia, motor dysgraphia and spatial dysgraphia, each characterised by specific alterations in the writing process.

In parallel, dysorthographia concerns the difficulty in applying spelling and syntactic rules, causing systematic errors such as omissions, substitutions or reversals of letters. The writing process follows a complex pattern involving the phonological route and the lexical route, both of which are fundamental to the correct spelling of words. Spelling difficulties can impair text production and negatively affect the quality of writing.

Early identification of dysgraphia and dysorthographia is essential to prevent repercussions on students' academic performance and motivation (Zucoloto & Sisto, 2002; Galaburda & Cestinick, 2003; Cervéra-Mérida & Ygual-Fernández, 2006; Manzano *et al.*, 2008; Giaconi, & Capellini, 2015). Various assessment tools, including standardised tests and observation protocols, allow risk indicators to be identified as early as preschool. The integration of digital technologies and artificial intelligence algorithms offers new perspectives for the automated analysis of handwriting, making it possible to collect detailed data on graphomotor parameters and to refine intervention strategies (Maniscalsco *et al.*, 2015; Giaconi and Capellini, 2015; Ceccacci *et al.*, 2024).

Current research emphasises the importance of school-based prevention and technological innovation to support students with writing difficulties by promoting inclusive and personalised approaches (Galaz *et al.*, 2020; Devillaine *et al.*, 2021; Dui *et al.*, 2020; 2022). The use of digital tools for monitoring graphomotor skills can facilitate the early detection of difficulties and guide the development of targeted interventions, contributing to the improvement of writing skills and scholastic success.

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3. Assessment and training of grapho-motor skills through adaptive technologies: the E-Hand project

by *Ilaria D'Angelo* and *Aldo Caldarelli*

1. Introduction

As noted in the previous chapter, among the current critical issues that pedagogy and special didactics have to face, there is the relationship between writing and technology, up to the relevant field of prevention, observation and intervention of dysfunctional processes of dysgraphia (D'Angelo *et al.*, 2020). Currently, technologies allow for a detailed analysis of various parameters and indicators related to handwriting. These include aspects such as the acceleration and pressure exerted during writing (Giaconi & Capellini, 2015), as well as the angle of the writing instrument. In addition, it is possible to focus on the micro-movements involved in the writing process, analysing elements such as grip, finger position, fine co-ordination, hand and shoulder movements, posture and pressure applied on paper or digital device.

Insofar there is no available e-learning system to support contemporary and conjunct identification of motor skill problems at an early stage, that could be related to dysgraphia. For these reasons, the project called "E-Hand. Empowering Middle Childhood Handwriting"[1], which we will present in this chapter, will address

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developments in novel technologies based on the concept of adaptive tutoring to design innovative training aids to detect early writing difficulties, allowing to intervene at an early stage for possible dysgraphia issues.

2. How to empower graphomotor skills through technologies

As mentioned in the previous chapters, various tools have been developed in the technological field to support handwriting. Current technologies allow for the collection and digitisation of numerous parameters and indicators during handwriting, such as acceleration, pressure (Capellini *et al.*, 2020), pen tilt (Asselborn *et al.*, 2020) and micromovements (Simeoli *et al.*, 2020). These parameters include grip, finger position, fine coordination, hand and shoulder movements, posture, and pressure applied to paper or tablet rather than macro movements (Rosenblum & Dror, 2016). Some tools are useful for analysing fine motor movements, such as smart pens that can capture handwriting data in real time, recording essential elements such as speed, pressure, and angle, and digitising handwritten notes. Additionally, graphics tablets (e.g., Wacom or iPad) paired with styluses (e.g., Apple Pencil) offer advanced tracking of pressure sensitivity, tilt, and micromovements, allowing for accurate recording of grip, finger positions, and hand coordination (Ceccacci *et al.*, 2024).

Among the current technologies, haptic technology is garnering increased interest in collecting dynamic and spatial information during drawing activities, which can be helpful in the early detection and identification of motor skill dysfunction. Portable and accessible haptic systems could serve as a viable complement to school-based training interventions to enhance functional writing outcomes (Park *et al.*, 2019; Palsb *et al.*, 2011; Fisachkerly *et al.*, 2010). However,

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these devices have primarily been evaluated on simple motor tasks (Sigrist *et al.*, 2013), and their effectiveness on more complex tasks, like handwriting, has yet to be confirmed. Furthermore, when used in passive mode, the same haptic instruments could enable the collection of dynamic and spatial data during drawing tasks to identify motor dysfunction early.

To comprehensively understand students' writing performance, it is crucial to monitor their posture and level of engagement (or interest) in completing learning tasks (Nicholls *et al.*, 2015). To this end, body- and hand-tracking systems based on RGB cameras (e.g., Agostinelli *et al.*, 2021) are particularly suitable for monitoring students' posture during writing activities due to their low cost and non-invasive nature. They can detect facial expressions, gaze direction and head posture (e.g., Whitehill *et al.*, 2014; Generosi *et al.*, 2020). Most of these systems are based on convolutional neural networks (CNNs) (e.g., Generosi *et al.*, 2018). Typically, these systems use models trained on datasets created in controlled environments for high accuracy or on web-collected data via crawlers, which, although less accurate, are more representative of real-world contexts. Data from these different sources can be correlated with learning indicators through data multimodality, facilitating personalised teaching (Di Mitri *et al.*, 2018). Several systems have been proposed to assist teachers in assessing and monitoring students' graphomotor skills (e.g., Celine & Jimmy, 2022) or to help train these skills using haptic devices (e.g., Park *et al.*, 2021). However, no integrated system currently combines both detection and training/monitoring features.

For these reasons, we are going to present a new technological framework that, while grounded in the scientific basis concerning the risk indicators underlying screening protocols, proposes an innovative perspective in designing a technological system that is more functional for observation and intervention in the school context, by integrating digital technologies, advanced educational methodologies and analysis tools to offer customised support.

3. The Technological Framework

As seen in another work (Ceccacci *et al.*, 2024), the proposed system integrates a Decision Support System (DSS) with intelligent tutoring capabilities designed to assist teachers and trainers in detecting graphomotor skills that impact writing. By analysing writing performance and motor coordination, the system facilitates the acquisition of data useful for both predicting the signs of dysgraphia and for carrying out specific support training.

This adaptive system integrates machine learning algorithms and data analysis with evidence-based teaching methodologies, creating a comprehensive approach to detecting and addressing writing difficulties.

As shown in Figure 4, during writing activities, the system collects different types of information, such as body posture, hand prehension and details of the movements and micromovements of the writing act (e.g. pressure, speed, latency, duration), in a non-invasive manner.

Figure 4. The proposed system

Data pertaining to the kinematics and dynamics of graphic strokes can be accurately captured using a Wacom graphics tablet, such as the Wacom Intuos Pro M, in conjunction with a smart pen, like the Wacom Ballpoint Pen. This data can then be exported using the Wacom Software Development Kit (SDK)[2]. This approach facilitates the collection of vital information at each time point, including pen coordinates (X, Y, Z), orientation, rotation, as well as both standard and tangential pressures: parameters that are recognised as standard metrics for monitoring graphomotor skills (Capellini *et al.*, 2020; Asselborn *et al.*, 2020; Simeoli *et al.*, 2020).

To effectively monitor body and hand posture, the system employs a motion analysis tool analogous to that described in Altieri *et al.* (2020). To enhance the accuracy of tracking body segment angles, three RGB cameras are strategically positioned to capture data from the transverse (top-down), coronal (frontal), and sagittal (lateral) planes. By analysing the estimated joint angles, the system identifies five distinct postural patterns, as defined by Vaivre-Douret *et al.* (2021), which serve as phenotypic markers of graphomotor gestures.

These patterns are instrumental in evaluating the development of motor control during writing, encompassing: pattern 1 (hand rotation at the wrist), pattern 2 (wrist movement in flexion-extension), pattern 3 (lateral trunk movement), pattern 4 (lateral forearm movement), and pattern 5 (forearm rotation at the elbow). Moreover, to differentiate hand posture, the system utilises convolutional neural network (CNN)-based deep learning algorithms, mirroring those proposed by Wu *et al.* (2022).

The system operates based on two principal models:

- Student model: this model leverages data mining and machine learning techniques to create a comprehensive profile for each child. It analyses writing performance (e.g. legibility, speed, and pressure), body and hand postures. The

[2] Specifically, a Wacom SDK graphics tablet in combination with MovAlyzeR® software was used for computerised handwriting evaluation. The execution of the experimental procedures required the use of a notebook connected to a digitising tablet (Wacom SDK equipped with a pen and touch surface).

model identifies gaps in motor coordination, postural challenges, and learning preferences, providing actionable insights for teachers to implement individualised interventions.

- Domain model: this model is centred on advancing motor skills and writing capabilities, organising crucial concepts such as fine motor control, pencil grasping, and stroke formation into a hierarchical structure. This structure ensures that learning tasks are presented logically, progressing from fundamental motor skills to more sophisticated graphomotor tasks. The system employs a knowledge ontology to represent the relationships between skills and requisite competencies.

The system serves a dual purpose: it can be utilised to assess students' graphomotor skills as well as to monitor their progress along a designated learning trajectory. During assessments, the system offers a series of exercises through a user interface on the tablet screen. By tracking a student's progress, the system generates extensive information that can assist educators in adjusting the learning path or providing emotional support should the child exhibit signs of frustration. Continuous monitoring of motor coordination and posture state allows the system to collect data that enables the customisation of the difficulty and nature of the exercises provided. For instance, if a child encounters difficulties with fine motor tasks, the system can recommend simpler exercises or additional haptic feedback to facilitate skill development.

Additionally, it can identify early indications of graphomotor difficulties, such as improper grasping or inconsistent pressure application, and provide teachers with valuable insights for targeted interventions aimed at improving writing performance. This approach ensures students remain engaged by presenting them with appropriately challenging tasks.

The system facilitates haptic training to enhance graphomotor skills through the use of 3D Systems' Geomagic Touch X device, which provides six degrees of freedom (6 DoF) and high-fidelity force feedback. The accompanying application is developed in Unity 3D, leveraging 3D Systems' OpenHaptics Unity plugin, and is

displayed on a PC monitor. The interface enables users to manipulate virtual objects using a virtual probe controlled by the haptic device, which functions as a stylus within the virtual environment. The objects in an orthogonal view on the screen enable precise interaction with surface features. When the tip of the virtual stylus contacts a virtual object, the Touch X device delivers force feedback that simulates the resistance of the virtual material, aligning with the

4. The piloting step

Entering into the merits of the Student model, which we shall examine in the present discussion for reasons of economy, the proposed system thus conceived was used in the piloting phase to realise two distinct applications: one aimed at children in the last year of preschool (5-6 years), which was carried out during the first four months and was directed at a sample of 62 children of whom 28 boys and 34 girls (belonging to the same school district, but placed in 4 separate sections); and, one aimed at children in the first year of primary school (6-7 years) carried out during the last four months and directed at the same sample.

The proposed set of exercises made it possible to examine some crucial variables in writing. The main ones being analysed include:

- Stroke size: vertical, horizontal and absolute (in cm);
- Times: from the start (from signal to writing) i.e. latency, total stroke length (in sec) and writing speed;
- Fluidity and pressure: normalised jerkiness and average pen pressure;
- Oculo-manual coordination, visuomotor and visuospatial skills;
- Fine manual dexterity: accuracy and continuity of gesture;
- Management of space in the sheet;
- Recognition and short-term memory and sequential visual memory.

Another relevant aspect is the grip, assessed with Schneck & Henderson's (1990) five-level scale:

1. Initial grip: radial cross palm (whole arm movements).
2. Intermediate: supinated palmar and pronated digital (still limited control).
3. In development: brush grasp and extended fingers (more precision, but wrist- and arm-driven movements).
4. Stable but rigid: cross-thumb, static tripod and static quadrupod (fair control, but little fluidity).
5. Optimal: lateral tripod and dynamic tripod (maximum precision and minimum fatigue).

Finally, an essential aspect in the analysis of handwriting is the assessment of the child's overall posture. Postural monitoring involves observing the position of the back, neck, shoulders and upper limbs, as correct posture reduces the risk of muscle fatigue and promotes greater concentration during writing activities. The data collected makes it possible to ascertain whether the child assumes postures conducive to comfort and accuracy or whether dysfunctional postural patterns are present that could impair the effectiveness of writing.

For the assessment of posture, two cameras are used, positioned frontally and laterally respectively. The variables measured include:

- Posture: head movement and tilt, shoulder movement, arm movements; deviations of the trunk axis;
- Bilaterality;
- Motor sequence planning;
- General macro- and fine-motor control.

4.1 Examples of piloting in primary school

The data obtained from the preschool children's assessments were carefully analysed by a team of experts who examined every aspect of the students' performances. The detailed results were then forwarded to the teachers with the aim of giving them a clear view of the areas in need of targeted intervention. The teachers, based on the information received, then activated specific and customised training programmes. These programmes were designed to specifically

enhance the dimensions of writing prerequisites that had emerged as most critical during the data analysis. In particular, they focused on aspects such as hand-eye coordination, visuospatial, speed, posture and grip, providing students with the necessary tools to improve and consolidate their skills in these fundamental areas, both through the use of the proposed system and additional sessions they designed.

In order to ensure an effective longitudinal perspective, a data collection system was structured to assess the development of the writing components one year later. The assessment was, therefore, carried out for the same students during the first year of primary school (in the last four months). Some children with the change of systems opted for a different school, so the initial sample experienced a negative drop of 13 students.

Specifically, in addition to repeating the same exercises administered to investigate the key components useful in identifying whether the initial dimensions of handwriting have changed over time, two minimal pairs of Italian words were added: "*Cigno/Ciglia*" (swan/eyelash) and "*Forza/Forca*" (force/fork) which allowed an even deeper investigation into the parameter of "time" in reference to writing. These pairs were strategically chosen for their phonological and orthographical similarity, thus enabling a specific investigation of subtle differences in the written production of closely related words. For each of these four words, some of the key parameters of the writing process were investigated. In detail:

- Latency: the reaction time, i.e. the interval between the presentation of the stimulus and the actual start of writing. Latency provides, in fact, valuable information on preliminary cognitive processes, such as speech recognition and motor planning.
- Writing speed: i.e. the speed with which participants perform the writing movement, offering specifications on the fluidity and automaticity of the production process.
- Total duration: i.e. the total time required to complete the writing of a word, from beginning to end. This parameter incorporates both the speed of execution and any pauses or hesitations during writing.

The parameters were investigated by asking each child to transcribe the word displayed on the graphics tablet immediately after its presentation on the screen (Times New Roman, 18 pt, printed in uppercase), using only capital letters.

For the sake of economy, in the following section we will only highlight the data obtained from the second test, referring to a sample consisting of 39 children in the first year of primary school, with regard to the performance obtained when writing minimal word pairs.

5. Data collected

For the word "*Forza*", among 39 children the average latency obtained is 1.023 seconds, with a minimum of 0.015 seconds and a maximum of 3.353 seconds. The average velocity is 3.588 seconds, ranging from 2.280 seconds to 5.654 seconds. The average duration is 3.091 seconds, with a minimum of 1.811 seconds and a maximum of 4.014 seconds (Tab. 3).

Tab. 3 - Word values: FORZA

	Max	Min	Average
Latency	3.353	0.015	1.023
Speed	5.654	2.280	3.588
Duration	4.014	1.811	3.091

As far as "*Forca*" is concerned, the average latency is 0.992 seconds, with a minimum of 0.752 seconds and a maximum of 1.200 seconds. The average velocity is 4.743, ranging from 3.150 to 7.203. The average duration is 2.390 seconds, with a minimum of 1.750 seconds and a maximum of 3.060 seconds (Tab. 4).

Tab. 4 - Word values: FORCA

	Max	Min	**Average**
Latency	1.200	0.752	**0.992**
Speed	7.203	3.150	**4.743**
Duration	3.060	1.750	**2.390**

As for "*Ciglia*", the average latency is 1.050 seconds, with a minimum of 0.090 seconds and a maximum of 2.330 seconds. The average velocity is 4.278, ranging from 2.331 to 6.517. The average duration is 3.206 seconds, with a minimum of 1.707 seconds and a maximum of 7.308 seconds (Tab. 5).

Tab. 5 - Word values: CIGLIA

	Max	Min	**Average**
Latency	2.330	0.090	**1.050**
Speed	6.517	2.331	**4.278**
Duration	7.308	1.707	**3.206**

Finally, for the word "*Cigno*", the average latency is 0.815 seconds, with a minimum of 0.270 seconds and a maximum of 1.210 seconds. The average velocity is 3.201, ranging from 1.634 to 5.099. The average duration is 2.051 seconds, with a minimum of 0.985 seconds and a maximum of 3.074 seconds (Tab. 6).

Tab. 6 - Word values: CIGNO

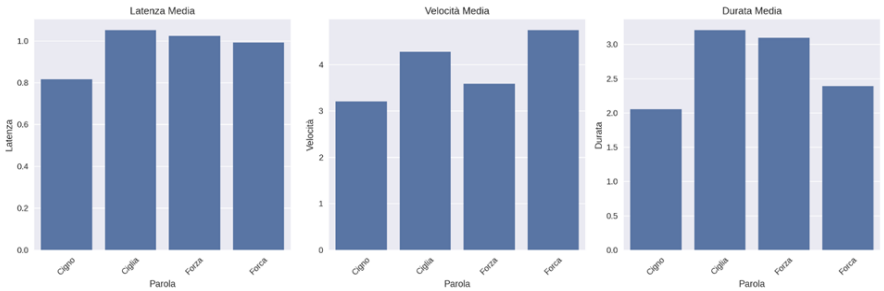
	Max	Min	**Average**
Latency	1.210	0.270	**0.815**
Speed	5.099	1.634	**3.201**
Duration	3.074	0.985	**2.051**

5.1 Analysis of data

The analysis of the data for the minimal pairs "*Cigno*/*Ciglia*" and "*Forza/Forca*" reveals interesting patterns in the written production of these words (Tab. 7). With regard to the first pair, "*Ciglia*" is distinguished by a generally higher latency and duration than "*Cigno*", while showing a higher writing speed. In the second pair, "Forza" and "*Forca*" have similar latencies, but "*Forca*" is written with a higher speed, while "*Forza"* takes a longer overall time to complete.

Looking at the parameters as a whole, it is observed that latency remains relatively constant between the words, fluctuating between 0.8 and 1.1 seconds, and shows less variability than the other parameters. Speed, on the other hand, shows a wider range, varying from 3.2 to 4.7 units per second, with "*Forca*" recording the highest average speed. Duration proves to be the parameter with the greatest variability, ranging from 2.0 to 3.2 seconds, with "*Ciglia*" taking the longest time to complete. Individual performances show considerable variability among the children involved, with some maintaining consistent patterns across words, while others show more variable performance. The correlations between the parameters offer further food for thought: latency and speed tend to be negatively correlated, while the strongest negative correlation is observed between speed and duration, especially for more complex words. From a statistical point of view, the differences between the minimal pairs are significant, with speed showing the greatest variability and latency being the most consistent parameter. These findings provide valuable information on the attentional and motor dynamics involved in the written production of similar but distinct words, opening up new perspectives for research.

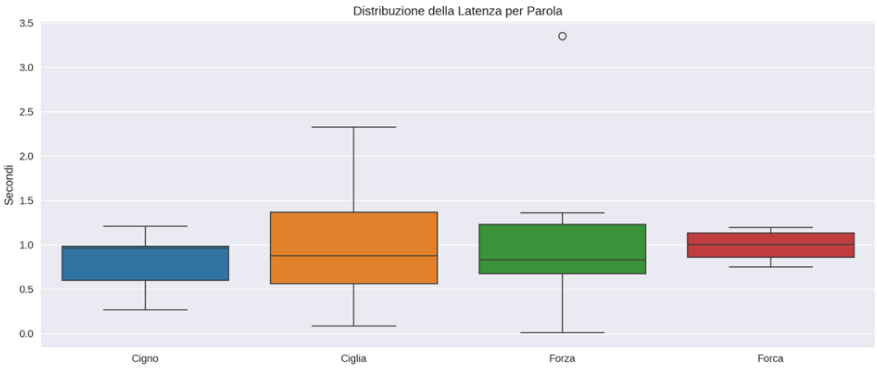
Tab. 7 - Graphical distribution of minimal pairs and relative parameter averages



A detailed analysis of the graphs and statistics for the three key parameters – latency, speed and duration – reveals interesting patterns in the written production of the minimal pairs "*Cigno/Ciglia*" and "*Forza/Forca*".

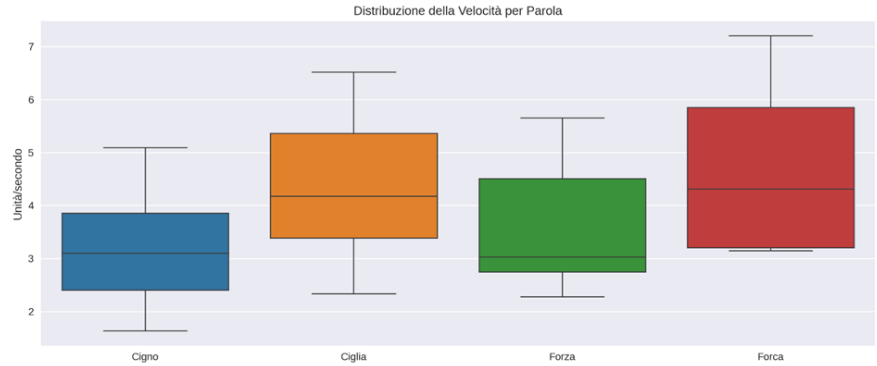
With regard to latency, depicted in table 8, there is significant variation between words. "*Cigno*" is distinguished by the fastest reaction time, with a latency of only 0.82 seconds, suggesting a rapid activation of the cognitive and motor processes required to initiate the writing of this word. At the opposite extreme we find "*Ciglia*", which requires the longest latency time of 1.05 seconds, possibly indicating greater complexity in initial processing or motor planning. The words "*Forza*" and "*Forca*" are placed in an intermediate position, with similar latency times between them, highlighting a certain homogeneity in the preparation phase for these two phonologically related words.

Tab. 8 - Graphical distribution of average latency per word



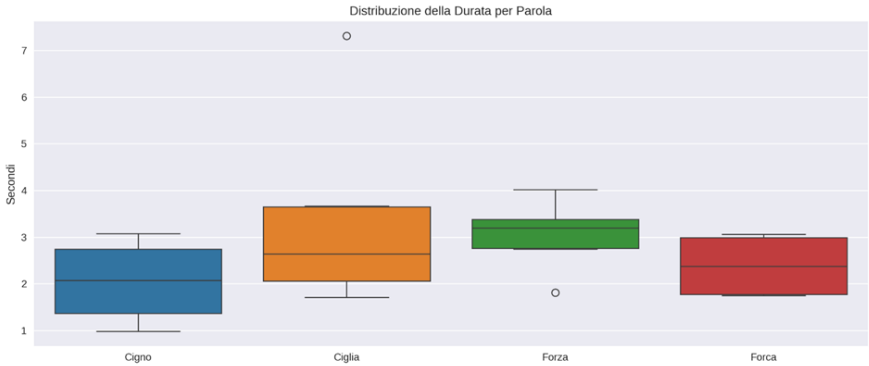
The second table (Tab. 9), illustrating writing speed, shows even greater variability between words. "*Forca*" emerges as the fastest written word, reaching a speed of 4.74 units per second. This could be attributed to a combination of factors, such as the simplicity of the required movements or greater automaticity in its production. In contrast, "*Cigno*" is written with the lowest speed, 3.20 units per second, possibly suggesting greater attention to detail or a more complex sequence of movements. Interestingly, speed shows the greatest variability among the three parameters analysed, indicating that this aspect of written production may be particularly sensitive to individual differences or specific word characteristics.

Tab. 9 - Graphical distribution of average speed per word



Finally, table 10, representing the total duration of writing, offers further food for thought. "*Ciglia*" stands out for taking the longest time overall, with a duration of 3.21 seconds. This, combined with its high latency and relatively high speed, suggests a more articulated writing process, perhaps characterised by pauses or adjustments during execution. In contrast, "*Cigno*" has the shortest duration, completed in just 2.05 seconds, despite its low writing speed. This could indicate a more direct and linear production process. "*Forza*" and "*Forca*" show intermediate durations, reflecting a balance between the various factors influencing the total writing time.

Tab. 10 - Graphical distribution of average duration per word



This in-depth analysis of the three parameters provides a complex and multifaceted view of the writing process for these minimal pairs, highlighting how each word presents a unique production profile, influenced by multiple cognitive and motor factors (Tab. 11).

The statistical analysis conducted on the word pairs "*Cigno-Ciglia*" and "*Forza-Forca*" offers interesting insights, although no statistically significant differences emerge at the conventional level of $p < 0.05$. The t-tests performed for each parameter – latency, speed and duration – reveal subtle trends that deserve careful consideration.

When comparing "*Cigno*" and "*Ciglia*", a slight tendency towards differences in writing speed and overall duration was observed, with p-values of 0.1710 and 0.1797, respectively. Although these values do not reach statistical significance, they suggest potential

differences in the production process of the two words. Latency, on the other hand, shows greater similarity, with a p-value of 0.4916, indicating relatively homogeneous reaction times for these two words.

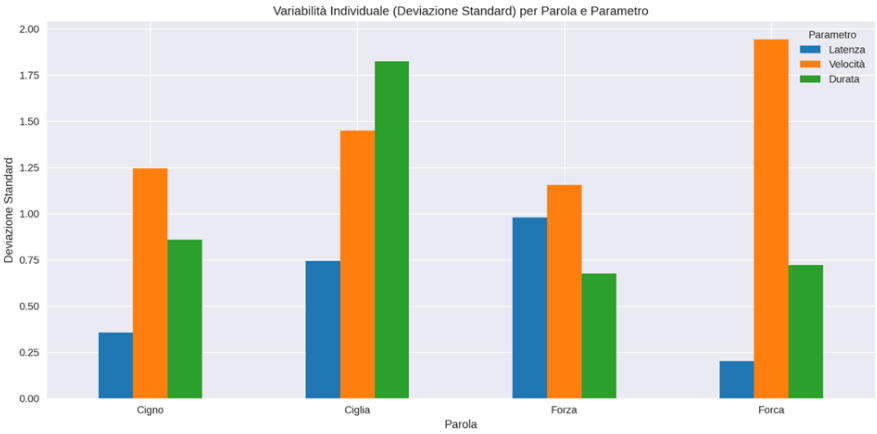
As for the "*Forza-Forca*" pair, a slightly different picture emerges. Latency is extremely similar between the two words, with a p-value of 0.9514, suggesting very similar initial processing. However, more pronounced trends are noted in the differences in speed (p-value 0.2018) and especially in duration (p-value 0.1189). The latter value, in particular, comes closest to the significance threshold, indicating a possible difference in the overall time required to write these two words.

These observations, while not reaching conventional statistical significance, offer valuable clues to subtle differences in the writing processes of phonologically and orthographically similar words. The trends that emerged, especially with regard to speed and duration, suggest the presence of specific mechanisms in the production of each word, which could reflect differences in motor planning, automaticity of the process or perceived complexity.

It is important to note that the absence of statistical significance does not necessarily imply the absence of real differences. Rather, these results invite further research, possibly with larger samples or more sensitive methodologies, to explore these trends in more depth. Furthermore, correlation analysis between the different parameters for each word could reveal specific patterns, offering further insight into the internal dynamics of the writing process.

In conclusion, although the statistical analysis does not provide conclusive evidence of significant differences, the observed trends open up interesting research perspectives. These results lay the foundation for future, more in-depth investigations into the cognitive and motor mechanisms involved in the written production of similar but distinct words, contributing to a more nuanced and complex understanding of writing processes.

Tab. 11 - Standard deviation by word and parameter



5.2 Implications/discussion

The data obtained with reference to the minimal pairs examined, "*Cigno/Ciglia*" and "*Forza/Forca*" reveal complex patterns that offer valuable implications on the processes involved in the act of writing.

The observed dissociation between latency and the other parameters (speed and duration) could indicate a common "phonological buffer", a motor preparation system that operates similarly regardless of the specific word to be written (Vygotsky, 1987; Fernyhough, 2016; Fernyhough & Borghi, 2023). On the other hand, the variability in speed and duration could reflect the activation of word-specific lexical and motor representations. This aligns with the two-way models of language production already highlighted in the relevant literature (Coltheart *et al.*, 2001; Coltheart, 2006), suggesting that after the initial phonological activation, distinct lexical and sub-lexical pathways come into play that modulate motor execution.

The subtle but consistent differences between simple minimal pairs, such as those examined, highlight the complex interplay between phonological and orthographic representations in the writing process. The greater variability in speed and duration for these pairs suggests that, despite phonological similarity, their orthographic

representations activate distinct motor patterns. This phenomenon could be traced to "lexical competition" (McClelland & Rumelhart, 1981), in which similar representations compete for activation, influencing final motor performance.

The patterns observed, particularly the variability in speed, could reflect a continuum of automatism in written production, as highlighted in other research (Anderson, 1983; 2013). Faster written words (such as "*Forca*") could benefit from a higher degree of automation, requiring less attentional resources. Conversely, words with slower speeds but longer durations (such as "*Ciglia*") might imply greater involvement of executive control, perhaps due to their lower frequency of use or greater orthographic complexity.

Differences in duration, especially for more orthographically complex words, could reflect monitoring and self-correction processes during writing. This suggests an active role of metacognition in the writing process, in line with writing models that emphasise the role of "self-regulated learning" (Zimmerman & Risemberg, 1997; Zimmerman, 2013; McCombs, 2013; Garcia & Pintrich, 2023).

The observed differences in writing parameters could also reflect the activation of partially distinct neural networks. Latency could be mainly associated with activity in the inferior frontal and superior temporal areas, which are involved in language planning. Speed and duration, on the other hand, may reflect more activity in the motor and premotor areas, as well as in the cerebellum, which is crucial for fine coordination of movements. This interpretation aligns with the neurocognitive models of writing proposed by Planton *et al.* (2013).

The results offer interesting insights into the incremental nature of learning to write. Inter-individual variability suggests that the acquisition of efficient orthographic and motor representations is a gradual and non-linear process, as writing expertise develops through progressive refinement of representations and optimisation of motor programmes (Ericsson *et al.*, 1993; 2003; Ericsson & Harwell, 2019). For these reasons, the dissociation between the various parameters confirms that the dysgraphia disorder could manifest itself not only as a generalised difficulty in the act of writing, but

specifically in its components of the writing process (e.g. in initial planning vs. motor execution).

This in-depth analysis reveals that the writing process is a multi-componential phenomenon that integrates linguistic, motor and metacognitive processes. The subtle differences observed between similar but distinct words highlight the complexity and specificity of the representations involved in written production. These results not only enrich our theoretical understanding of the mechanisms underlying writing, but also offer practical implications for training. The evidence, in fact, raises significant implications for the personalisation of teaching and intervention strategies, highlighting that uniform approaches may not be optimal for all students.

In conclusion, this analysis not only provides a deeper understanding of the writing processes for similar but distinct words, but also opens up the implementation of pedagogical approaches based on detailed empirical evidence on the one hand, and new perspectives for interdisciplinary research integrating neuroscience and linguistics on the other.

6. To summarise

The analysis of graphomotor skills in children represents an area of growing interest for educational and pedagogical research, with the aim of early detection of possible difficulties and targeted intervention (Giaconi & Capellini, 2015; Ceccacci *et al.*, 2024). The use of digital technologies has opened up new perspectives for the observation and evaluation of handwriting, making it possible to collect detailed data on crucial aspects such as the pressure exerted during the stroke, the acceleration and speed of writing, the inclination of the instrument and the micromovements of the hand and fingers. The systematic collection of these data makes it possible to develop intervention strategies aimed at collecting useful data both to predict possible criticalities during writing activities and to carry out specific training.

The experiments conducted in the “E-Hand. Empowering Middle Childhood Handwriting” project presented here, aims to contribute

significant data on the development of graphomotor skills in preschool and primary school children, highlighting progress and critical points at the different stages of learning to write. In particular, as presented in the course of the study, the analysis of minimal word pairs allowed for an in-depth study of the temporal dynamics of the writing process, highlighting the relationship between latency, speed and duration of the graphic stroke.

In this context, the use of advanced digital tools, coupled with educational methodologies based on data analysis, emerges as a fundamental resource for the early detection of potential writing-related difficulties as well as for the enhancement of writing skills.

The results obtained suggest the adoption of a multi-systemic and integrated approach, combining observation, technological innovations, targeted teaching strategies and specific training, with the aim of significantly improving the quality of writing and contributing to the development of more fluent and automated skills in children.

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Conclusions and inclusive trajectories

by *Noemi Del Bianco*

In order to outline the main pedagogical lines, useful for the implementation of inclusive contexts, in this chapter we will conclude our reflection by highlighting some fundamental dimensions for the educational care of students with SpLDs.

The first area that presents itself as central is that of prevention, with a focus on the dissemination of a preventive culture. In this regard, Special Pedagogy (Giaconi & Capellini, 2015) suggests promoting early and careful observation of students in learning contexts and the definition of possible lines of intervention on reading, writing and calculation prerequisites. Another key step is the introduction of school screening, which should be started already in the last years of preschool and the first years of primary school.

Alongside this, we also emphasise the integration of new technologies as support tools in the detection of possible signs preceding the manifestation of disorders. Given the growing research interest in this area, it is plausible to assume that the reliability and applicability of technologies in screening protocols will continue to improve as scientific and technological advances enhance their accuracy and effectiveness.

The integration of advanced digital tools will allow not only for the refinement of observation and screening protocols, but also for the early detection of possible difficulties, enabling timely and targeted interventions (Kunhoth *et al.*, 2024). Looking forward, these technologies could also be applied to school enhancement

programmes, contributing to a more effective management of learning difficulties. The school, as a constantly evolving environment, requires tools capable of adapting to an increasingly complex reality, in which the personalisation of teaching and support for students with special needs are fundamental aspects. Consequently, the adoption of evaluation and monitoring procedures that are timely, continuous and sustainable will increasingly become a necessity. In order to meet these challenges, technological tools will have to ensure multi-dimensional monitoring, capable of capturing the complexity of transversal development processes and, at the same time, provide a detailed analysis of specific learning areas. This approach will make it possible not only to identify any critical issues, but also to target educational interventions more effectively, promoting personalised and accessible learning for all students.

For instance, the use of Artificial Intelligence and Machine Learning systems could refine intervention strategies, allowing for more and more customised implementation methods. Predictive models developed through Machine Learning could, in fact, provide real-time suggestions to teachers, indicating which strategies are most effective for each pupil and which aspects need more attention. Adaptive software can calibrate the difficulty level of exercises according to the student's skills, providing immediate feedback and adapting content to maximise learning. This is particularly useful for students with graphomotor difficulties, who can benefit from handwriting-assisted tools and applications that promote fluidity of the graphic gesture.

As can be seen from the project proposal carried out, the observation of graphomotor skills, also made possible by the use of advanced technologies, made it possible to investigate the fundamental parameters of handwriting, such as pen pressure, stroke speed and fluidity, as well as the posture adopted during the act of writing (Engel-Yeger, Nagauker-Yanuv & Rosenblum, 2009). Technologies such as graphomotor analysis make it possible to collect data on movements and posture while writing, offering tools to monitor students' writing in real time and to identify dysfunctions in motor skills at an early stage (Penge, 2010). The use of innovative digital tools can therefore be seen as a significant opportunity to

improve the early detection of difficulties and to propose personalised interventions based on the objective analysis of collected data (Ceccacci *et al.*, 2024). The integration of technology and educational methodologies, as highlighted in the project "E-Hand. Empowering Middle Childhood Handwriting", represents a promising perspective in supporting students with SpLDs. The combination of digital tools for graphomotor monitoring and artificial intelligence algorithms for data analysis makes it possible to identify specific difficulties more precisely and to develop customised intervention strategies (Danna *et al.*, 2023).

The implementation of these technologies will also require an ongoing commitment to training school staff so that teachers are adequately prepared to use these tools and interpret them correctly. Indeed, the interconnection between technology and special pedagogy requires specific training for teachers so that they can make the most of the potential offered by the new digital tools. For these reasons, staff training appears to be a further point for reflection, as mere access to technologies is not sufficient for the realisation of inclusive learning environments without adequate preparation for the pedagogical use of these tools. The need to train teaching staff is not limited to the acquisition of technical skills of the tools but includes a broader dimension of methodological and critical awareness of their pedagogical implications, in order to ensure their effective integration into learning/teaching pathways. Teachers must, in fact, be able to assess the impact of technologies on the learning process and adapt them to the specific needs of each student, especially in inclusive contexts. This implies the acquisition of skills for the personalisation of teaching paths, the management of digital tools as support for special educational needs and the ability to interpret data collected by analysis software for a more targeted and effective educational intervention. Since inclusive teaching cannot be limited to the adoption of technological tools, but must involve an overall rethinking of teaching methodologies, favouring differentiated and personalised approaches (Giaconi & Capellini, 2015), truly inclusive teaching must therefore be based on flexible didactics that take into account the diversity of students, adapting materials, assessment methods and learning rhythms so as to favour the full participation of all. This

means rethinking the role of the teacher as a facilitator of the learning process, able to use new technologies to build stimulating and accessible educational environments.

The effective integration of digital technologies and educational strategies therefore requires a constant commitment to training, research and didactic experimentation, so that every student can benefit from a quality education, built on their abilities and potential. The evidence that has emerged in the previous chapters therefore underlines the need for a cultural change in the approach to SpLDs, which sees the school not only as a place for transmitting knowledge, but as an environment capable of adapting to the needs of each pupil. For these reasons, as Giaconi and Capellini (2015) point out, the creation of effective inclusive practices cannot be separated from a strong collaboration between school, family and university. Only through constant dialogue and synergetic work between research, technological innovation and inclusive education will it be possible to develop educational paths based on solid scientific evidence, but also on the experience and practical needs of teachers and students. This requires an ongoing commitment to the experimentation and implementation of new strategies that integrate the results of scientific research with everyday educational practices. Collaborative research between different actors in the educational world thus appears to be the key to making school inclusion not just a theoretical principle, but a concrete and effective reality for all students, including those with Specific Learning Disorders.

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This volume takes shape within the framework of the project of relevant national interest, with the aim of offering a scientific and operational contribution to the understanding of Specific Learning Disorders (SpLDs). Through a multi-chapter pathway, the text takes the reader from the theoretical framework on SpLDs to the specific analysis of Dysgraphia, highlighting the importance of early detection, prerequisite enhancement and the use of innovative educational technologies in promoting accessible and meaningful learning environments.
Targeted at teachers, educators, pedagogists, professionals and students in training, this volume proposes an educational model based on competent observation, personalized planning and shared pedagogical responsibility.

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