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# Towards the early detection of the red flags of dysorthography in non-diagnostic settings

Chiara Pugliese[1], Susanna Pelagatti[2]

[1] Dipartimento di Filologia, Letteratura e Linguistica, Università di Pisa, Piazza Torricelli, 2 56126 Pisa (Italy) - c.pugliese1(«»)studenti.unipi.it

[2] Dipartimento di Informatica, Università di Pisa, Largo Pontecorvo, 3 56127 Pisa (Italy) - susanna.pelagatti(«»)unipi.it

## ABSTRACT

Dysorthography is a specific disorder of spelling written words, for example confusing similar letters and putting letters or syllables in the wrong order. In Italy, recent studies estimate on average 30.711 children with dysorthography. This is a very large number, and an early detection becomes crucial to allow teachers and family to be aware of the difficulty encountered by a child in daily school activities and to start to address the problem. The goal of our project is to sustain tutors (teachers and parents) in this difficult path. This is achieved by giving them clear suggestions on the need of a professional evaluation through the analysis of some written text. We encourage them to purse this path with a simple friendly app which can be used in a natural environment, such as home and school. In this paper, we present the preliminary work for the participatory design of such an application. First, we identified a focus group to understand the most important red flags of dysorthography. The group included parents and teachers recruited in specific Facebook groups and professionals from Specific Learning Disabilities Centres. Then, we built a dataset from real handwritten text by children with dysorthography. The paper details both phases outlining the lesson learned and the strategy chosen for the main problems encountered.

## KEYWORDS

Dysorthography; deep learning; handwriting recognition.

## 1. INTRODUCTION

Dysorthography is one of the Specific Learning Disabilities (SLD) and concerns errors in spelling level of written words, such as confusion between similar letters and with the order of letters or syllables. In Italy, recent studies estimate a prevalence of 20.579 children with dysorthography aged 7-10, 36.177 children aged 11-13 and 35.378 children aged 14-18 [11]. An early detection of dysorthography is very important to allow the school and the family to be aware of the difficulty encountered in daily school activities and to start to address the problem. Nevertheless, many children with dysorthography and other SLD are not recognized and diagnosed until late primary school. This is due to the psychological and practical problems of spotting early red flags at home and in the classroom. When this happens, the children have a poor outcome, but they are considered lazy. Very often the teachers say something like “he/she is smart but does not work enough...” which worsens the situation since it adds some serious self-confidence issues to the SLD problem [5].

Sometimes the parents and teachers have some doubts but are simply worried to go through a proper process of diagnosis until they are really convinced that the problem might be real. A process of official diagnosis is often perceived as an admission of diversity which can be dangerous for the child future life [2]. Although the number of diagnosis is rising [11], this work [2] shows that many students with SLD remain without a diagnosis. The study was conducted on a group of 9.964 Italian children aged between 8 and 10, of which only 126 (1.3% of the total) had already a formal diagnosis of SLD. During the study, several standardized tests were administered to the group. After the survey, the percentage of the children with SLD had risen to 3.5%.

The goal of our project is to sustain families and teachers in this difficult path trying to give them clear suggestions on the need of a professional evaluation through the simple analysis of some written text. Though the real diagnosis can only be made by a professional team, our goal is to encourage family and teachers to purse this path. This is possible using a simple friendly app which can be used in a natural environment, such as home and school. We will discuss some related work in Section 2, however, to the best of our knowledge this is the first attempt to address this specific problem.

Our project follows the three-phase model proposed by Hevner [8]: an iterative process actively involving the stakeholder and the SLD specialists. We try to understand which are the red flags which needs to be taken into account and how to recognize them. In this paper, we will discuss the first stage of our project discussing the work done with a focus group including SLD people, parents, teachers, and doctors. The aim of this work has been to study people’s needs, to explore the experiences of those who received late diagnosis, to understand how parents and teachers noticed and discovered their

children's disorders, and to understand the best way to sustain them in this difficult path. This has been carried on through the usual methods including questionnaires, interviews, and dataset analysis.
From the results obtained we start to outline the needs and the strategies to be included in the future prototype app.
The paper is organized as follows.
Section 2 gives a brief overview of the state of the art. Section 3 describes our research method. Section 4 outlines the main ideas for the future app and gives details of our focus groups and of the results obtained. Section 5 concludes.

## 2. STATE OF THE ART

In the literature, there are some applications that support diagnosis of dysgraphia, another SLD concerning written level. These works are software created to support doctors in making diagnoses and to monitor patients with this SLD. Their aims are to reduce costs in term of time and to monitor written texts in an objective manner. For example, *TestGraphia* [6] is an Italian software system based on known document analysis algorithms. Starting from a digital image of written text, this software carries out *offline* handwriting detection. It extracts some features, called *static*, following the BHK (Concise Evaluation Scale for Children's Handwriting) Evaluation Protocol[1], such as left margin text alignment, writing size, etc. The offline approach starts from a digital image, processes it, and detects text area [12]. After feature extraction, it computes a score and returns a report. In this way, doctors can read the report and modify it when the results are not correct. In addition, the mean time to execute a diagnosis is nearly ten times faster with this kind of tool than without. In this way, doctors can monitor more than one patient in a short time.
Papers [1], [14] and [10] are based on *online* handwriting detection that require a technological support such as a consumer tablet [12]. These works add the possibility to extract more than *static* features. With the online approach, it is possible to extract *dynamic* features such as pressure and tilt of the pen. Dynamic and static features together help doctors to make a more accurate diagnosis and are important to identify other disorders such as dyspraxia.
All these works are created to support diagnosis, so the disorder was already identified by parents or teachers. Instead, in this paper, we present a tool able to detect the red flags of dysorthography when this disorder is not already known. So, the aim of our project is not to help doctors and support the diagnosis. It is useful to make known SLD as much as possible and to encourage to early diagnosis. In the end - while to detect the dysgraphia it is not necessary recognize text, but only monitor its dimensions, alignment, etc. - for our work the handwriting recognition is the key for the red flags detection.

## 3. RESEARCH METHOD

First, we identified a focus group - with the help of Facebook groups - to understand which are the red flags of dysorthography. The focus group is composed of 230 people, including 12 people with SLD, 19 parents of children without SLD and 199 tutors of children with SLD. We have designed an interview with which we have investigated the kind of the red flags and at what age they have arisen. Results confirmed the scientific data: the most common errors are confusion between similar phonemes (such as p/b, f/v, t/d), omission, insertion or inversion of letters or syllables (*palora* instead of *parola*) and omission of double letters or <h> in verb (*mama* instead of *mamma*) [7]. Instead, about the age, 24.78% of participants identified the red flags from age 8 and up (11,74% after age 10). This means that in 57 cases out of 230 the diagnosis was made later than the recommended age (during the third grade [5]).
The next step was to contact the clinicians of the IRCCS Stella Maris Hospital and the educators of the DAB-LAB Centre for SLD to collect data of children with dysorthography. We managed to collect 181 texts based on standardized tests and written by 60 authors (Table 1).

| Grade level | Number of authors | Grade level | Number of authors |
|---|---|---|---|
| 1st grade school | 0 | 1st secondary school | 8 |
| 2nd grade school | 3 | 2nd secondary school | 1 |
| 3rd grade school | 17 | 3rd secondary school | 4 |
| 4th grade school | 9 | 1st high school | 2 |
| 5th grade school | 13 | from 2nd high school on | 3 |

**Table 1. Classification of handwritten text authors based on grade level.**

Once collected data and answers to the interview, it was possible to define problems to reach our aim. We can define three problems to be faced. The first one is to detect handwriting text starting from digital images and to segment these images in characters. Before proceeding with segmentation, it was helpful to pre-process images with some actions such

[1] A standardized method to detect dysgraphia.

as noise reduction, binarization, etc. For preprocessing and word segmentation we used built-in functions of OpenCV[2]. Instead, for character segmentation, we implemented algorithms following [3] and [13] because built-in functions cannot detect and segment every character in words. With these algorithms, we detected pixel intensities of each column of images, white spaces between characters (in uppercase) and ligatures in cursive texts (examples in Figure 1).

(a) (b)

**Figure 1. (a) Image segmentation with built-in functions. (b) Image segmentation with our implemented algorithms. Blue rectangles show detected area.**

The second problem is to proceed with the offline handwriting recognition of segmented characters. The last one is to detect typical errors in recognized texts. For both handwriting recognition and red flags detection we adopt machine learning approach such as most works in the literature [9]. We are experimenting different deep learning models such as Convolutional Neural Network (CNN) and Recurrent Neural Network (RNN), in particular Bidirectional Long-Short Term Memory (Bi-LSTM). Handwriting recognition models are trained with the EMNIST dataset [4], a set of 814.255 handwritten characters - in lower and upper case - and digits, written by 500 writers. Instead, red flags detection models are trained with our collected data to which we are adding texts without errors and other texts containing errors generated automatically, in order to obtain a larger dataset.

## 4. OUTLINING A DYSORTHOGRAPHY APP

Clinicians had some doubt about this project because it is impossible to say if a child has one or more SLD starting from any written text. When they make a diagnosis, they administer a set of standardized tests based on the child's age. When there is a number of errors above a certain threshold, they can make the diagnosis. But, after some meetings, they defined our work such as an activity of "pre-screening". So, our project will be useful to trigger doubts in tutors and to start monitoring children before the diagnosis.

In addition, after reading the focus group's answers, we realized that parents want to be understood, first of all. They do not want to be alone during the diagnosis path. They claim more attention on SLD by schools. Although they had doubted and did not understand very well how our project works, they were happy and grateful for our attention to SLD. For these reasons, the future app will be called *Dis-: not a problem* and will be designed as follow. First, there will be a section dedicated to the users. Here there will be a guide for using the app properly. It must be clear that this app does not make a diagnosis, but it does a sort of "pre-screening" activity. In this section we will also answer to the user's questions: what are SLD, how the app works and why they should use it. The core of the app will be a section where users upload images of child's handwritten text. In order to make the handwriting recognition more accurate, in this section, we will ask users if the text was written in upper or lower case. The output will be a "score" calculated considering the number of red flags, compared to the total number of words. Therefore, in the back-end, once the image is loaded, it will be pre-processed and segmented (such as described in Section 3) in characters. Every character will be the input of the handwriting recognition neural network. Accordingly, the output of this neural network will be the input of the red flags detection neural network. The final output will be the desired score. Concerning the front-end part, it should be as usable as possible: we will design it in according with indications of the focus group and main web design guidelines for people with SLD [15] (resume in Table 2).

| "Problem" | Solution |
|---|---|
| Confusion between similar characters (p/b, m/n, etc.) | Use OpenDyslexic[3] font |
| Difficulty to read lists | Use numbered lists |
| Difficulty to read with white background | Use pastel colours |
| Difficulty to read large texts | Use two columns |
| Difficulty to keep attention | Use short sentences and emphasized texts |

[2] https://opencv.org/
[3] https://www.opendyslexic.org/

| | |
|---|---|
| Difficulty in understanding | Insertion of explanatory images |

**Table 2 - SLD people's issues arising from the focus group and adopted solution, according web design guidelines for people with SLD.**

In addition, we will use a calm language in order to avoid alarming tutors. In Figure 2, the main sections app mock-up.

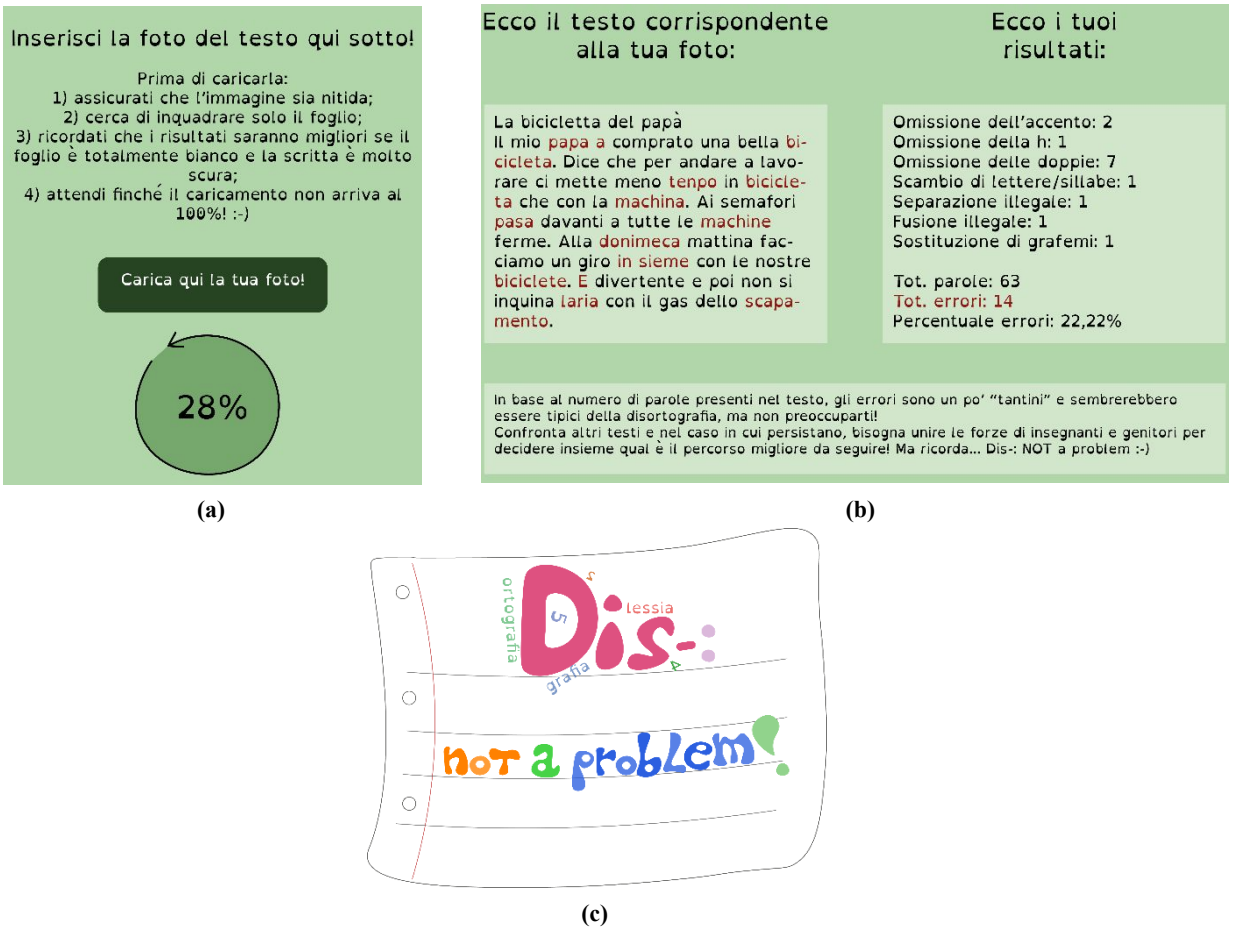


**Figure 2. The main sections of *Dis-: not a problem* mock-up. (a) Section where there is some information on how to make and to upload photo in the right way. (b) Section where the app returns plain text corresponding to digital image and output "score".**

## 5. CONCLUSIONS

Collecting the focus group's experiences, we have read many stories. In some cases, especially when the diagnosis was late, despite parents had had an intuition in an early age, the disorder was underestimated by teachers. In other cases, children's self-confidence was very low, or they had problems to remain seated on a chair. In extreme cases, children were so frustrated to be led to act of self-harm. Many parents complained about the poor preparation of teachers on the subject or their superficial attitude. Some other families complained about the very long time taken by the diagnosis process. Instead, in some cases, there was a good cooperation between parents and teachers. In Italy, this is very important because the path of a diagnosis cannot start until teachers finish a six-month monitoring period. In this period, teachers try to understand if there is a persistent problem or if the child has fallen behind, compared to the rest of the class. However, the most part of the focus group had not a good experience.

So, this research and app want to be a way to reach "lost children". If this application is used in a natural environment such as school or home, more children with dysorthography, but without a tutor expert in this disorder, will be helped in time. In addition, our aims are to make this problem known as much as possible and to encourage tutors to take a path with professional teams. Our choice to use offline approach for handwriting recognition was driven by our desire to not force users to necessarily buy an expensive tablet.

In order to improve our work, we will continue to collect data, which are very important to train neural networks correctly. Moreover, it would be useful to implement a personal area where each user could monitor every text analysed, with the corresponding score. In this way, it is possible to monitor children's performance and to observe their improvements.

In the end, a valid improvement could be to extend functions of Dis-: not a problem to the other SLD. We have decided to work with the dysorthography first for some reasons. The most important are because this disorder - together with the dyscalculia - is less known than dyslexia and dysgraphia and because there are already works related to dysgraphia.

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