

A Web Application for Reading and Attentional Assessments

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ABSTRACT

This work aims to design and develop a web application for reading and attentional evaluation in schooling children using a standardized tests battery. The application allows the automatic and immediate calculation of child's scores by inserting times and errors committed by the subject. The obtained scores are needed to establish whether the participant's performance is in deficit or not (i.e., Z-score).

CCS CONCEPTS

• **Applied Computing** → *Psychology*

KEYWORDS

web application, reading assessment, attentional assessment, Ruby on Rails

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1 Introduction

For about 10% of people reading acquisition is extremely difficult due to a heritable neurobiological disorder called developmental dyslexia (DD). Individuals with DD have difficulties with accurate

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and/or fluent word recognition and spelling, despite adequate intelligence, sensory abilities and academic instructions [1, 2, 3]. DD is defined by difficulties with decoding grapheme into phoneme, by comparison with comprehension and DD is often associated to an impaired phonological awareness, which refers to the ability to perceive and manipulate the sounds of spoken words [4]. However, children with DD often show also visuo-spatial attention deficits and new evidence demonstrates that this deficit is a cause of DD [5, 6, 7, 8]. In this way the DD is considered a multifactorial disease.

For this reason, it is important to evaluate both reading [9] and attentional skills during an assessment for both diagnosis and rehabilitation treatment efficacy evaluation of a child with DD. To correctly assess reading and attentional skills standardized, tests are necessary. To date, few tests are available for the assessment of reading and attentional skills in the Italian language. Furthermore, these tests require an expensive work for the clinicians that must calculate the raw data (i.e., time and errors of the performance of the patient) and transform these data into standardized data to know whether the performance of the patient is impaired or not.

The aim of this study is to create a web application able to facilitate the work of the clinicians in reading and attentional assessment. This web application is an evolution of a series of tests for reading and attentional evaluations, *De.Co.Ne. Reading Tests* [10] and *De.Co.Ne. Attention Tests* which are standardized in a group of 467 primary school Italian children. The average values of these tests can be used as reference values from the application to compare the performance of the considered subject with the average performances.

The tests, which are also available on our website (<http://dpg.unipd.it/en/deconelab>), are offered as a useful alternative for the assessment of reading and attentional skills, before and after rehabilitation training, and reading and attentional screening.

In the reading tests section there are 4 tests to evaluate the word and pseudoword reading skills. In the attentional tests section there are 5 tests to evaluate the orienting and focusing of attention and the inhibition of flankers.

Our web application does not replace the work of the examiners to evaluate the child. Indeed, the tests are conducted by the examiner, but this web application simplifies the work of the examiner to measure the time (by an integrated chronometer) and errors of the child performance.

Furthermore, once the examiner ends the test, she/he stops the chronometer and enters data about the errors; at this point, the web application automatically calculates the standardized scores of the child. In this way the examiner becomes aware of the possible presence of any deficit. Another benefit is the possibility to extend the web application in several ways, in order to improve the system performance or to add new features (e.g., new languages). Finally, our web application can start the same test for the same subject several times, to check any effects of rehabilitation training by that patient. We used our application with Italian tests, but for the sake of clarity, in the paper we show screenshots translated into English.

2 Method

2.1 Reading Tests

2.1.1 Test 1: word lists

This test contains three lists of 17 words each. The words are composed by 2-5 syllables (4-10 letters, font Arial, size 14). The total number of syllables is 149. The subject, in each column, has to read the words in a rapid and accurate way. At the end, the examiner takes note of the number of errors and the execution time.

2.1.2 Test 2: pseudoword lists (2, 3, and 4 syllables)

This test contains three lists of 10 pseudowords each. In this context, pseudowords are orthographically sequences of letters with no meaning but that resemble actual words. The pseudowords of the first list are composed by 2 syllables (40 letters, font Arial, size 14), those of the second list are composed by 3 syllables (70 letters), and those of the third list are composed by 4 syllables (89 letters).

The test is composed by 90 syllables. The subject, in each column, must read the pseudowords in a rapid and accurate way. At the end, the examiner takes note of the number of errors and the completion time. In Figure 1, an example of pseudoword lists is provided. At the bottom we can see three fields to fill: Time, Errors and Syllables/Second.

2.1.3 Test 3: pseudoword short lists

This test contains two lists of pseudowords, each one composed by 50 syllables (108 letters, font Arial, size 14). At the end, the examiner takes note of the number of errors and the completion time.

2.1.4 Test 4: pseudoword texts

This test contains 2 texts, each one composed by 46 pseudowords, for a total of 100 syllables (200 letters, font Arial, size 14). At the end, the examiner takes note of the number of errors and the completion time.

sipa	cheloma	dravelire
rage	begnole	cegirate
pave	iraglio	chetinere
puce	fattero	machidare
seca	dascimi	miferisce
maco	rignaso	ravicezza
cofo	poritta	egnomisa
vuso	frimace	cagliralo
save	caglire	pagritene
soce	pusceda	taglicosi
Time: _____	Time: _____	Time: _____
Errors: _____	Errors: _____	Errors: _____
Syll./sec.: _____	Syll./sec.: _____	Syll./sec.: _____
Total Time: _____		
Total Errors: _____		
Total Syllables/sec.: _____		

Figure 1: An example of pseudoword lists test, with time, errors and syllable fields on each column and on total.

Figure 2: An illustration of the bars presented in the test.

2.2 Attentional Tests

2.2.1 Test 1: bars test

This test contains two columns of bars. Each column contains 24 lines with a different number of bars in each line. The first column contains three to six bars in each line, and the second column contains four to seven bars in each line. The bars in the first column are aligned with the centre of the sheet whereas the bars in the second column are not. The child has to state the number of bars in each line. At the end, the examiner takes note of the number of errors and the completion time. In Figure 2, an example of the first column is shown.

2.2.2 Test 2: C maze test

This test is composed of 3 tests. Each one contains a maze of open circles with different orientations and the child has to lead a target from the position A to the position B (see Figure 3). The examiner takes note of the number of errors and the completion time.

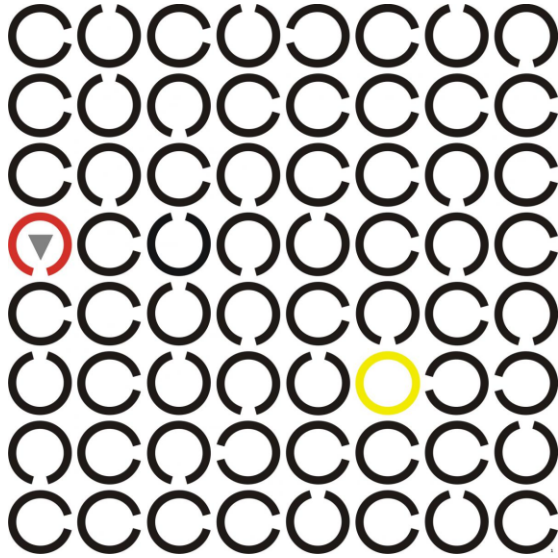


Figure 3: An example of attention test: the C maze test.

2.2.3 Test 3: Geometric shapes denomination test

This test is composed of two parts: congruent condition and incongruent condition. In the former there are 21 geometric shapes divided into 3 lines each one of 7 geometric shapes. The geometric shapes are circle, square and triangle. Each one is composed of small geometric shapes. In the congruent condition the big and small shapes are the same (e.g., a big square composed of small squares); in the incongruent condition the big and the small shapes are different (e.g., a big square composed of small circles). The child has to perform a global and a local task. In the global task the child has to recognize the big shape, while in the local task the child has to recognize the small shapes. At the end, the examiner calculates the number of errors and the completion time.

2.2.4 Test 4: Images denomination test

This test is composed of a set of the same image with three different orientations. According to the orientation, the image is associated to a rhino, a fish and a penguin. During the training phase the child learns the names of these three different images. Afterwards, the child has to recognize them in a frame composed of 33 images (as said, the same image with different orientations) divided in 3 lines with 11 images in each one. At the end, the examiner calculates the number of errors and the completion time. In Figure 4, the images are shown. At the top, the 3 images in their context presented in the learning phase (respectively fish, penguin and rhino), while at the bottom the same images without the context presented in the test phase.

2.2.5 Test 5: Letters denomination test

This test is composed of letters P, F, and M. The test contains 3 lines each one with 11 letters. The child has to recognize the letter. At the end, the examiner calculates the number of errors and the completion time.

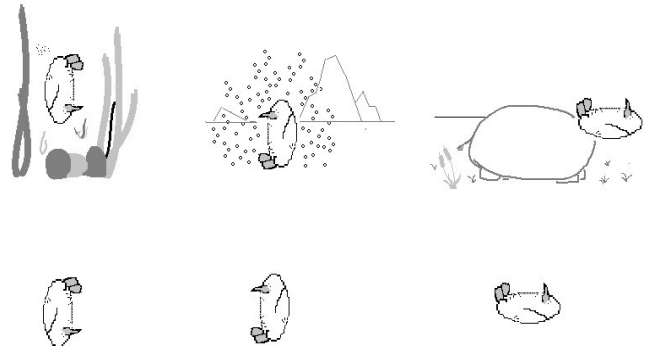


Figure 4: The training set images and the same images presented in the test session.

3 Related Work

Previous works considered methods to detect and analyse dyslexia adopting information technology like applications, games and mobile devices. We here provide just a concise, although representative set of recent examples.

In [11] a web-based game is exploited to reveal differences in children of diverse languages with and without dyslexia. The authors of [12] propose a game to train children with dyslexia and improve their performance in terms of working memory, executive functions, perception, etc. The work in [13] presents an evaluation of DysWebxia, a reading app for iOS devices designed for people with dyslexia, providing an improved text visualization.

To the best of our knowledge, there is no application for the examiner side that processes multiple subjects data analysing their statistical results.

3 The Web Application

In this section, we describe the implemented web-service, its technology and functionalities. Please note that, since the case study is originally in Italian language, for sake of clarity the shown text of the web application is translated in English language.

3.1 Motivation

Generally, the tests of reading and attentional assessment are made using a paper form in which the examiner writes the subject information and the test results (time and errors). Then, for the calculation of Z-score and percentile, a spreadsheet provides all the reference parameters (averages values) needed.

This approach is slow, not flexible and not sharable: if other clinicians from different cities or countries need that spreadsheet reference to perform the same test method, they must contact who owns it. Furthermore, it lacks privacy and security. Finally, it is not error proof, subject to human errors.

A web application that substitutes all the test steps, could improve several aspects.

First, the test execution time (from the examiner point of view), which is reduced thanks to the use of a unique web interface to which enter the data and the automatic scores calculation.

A second advantage is the possibility to monitor the results time by time, simply comparing them on the web application.

The web application gives to remote clinicians the possibility to use the assessment method, increasing its visibility to the community of researchers that focus on reading and attentional difficulties.

Privacy and security can be enforced by providing to each examiner an account, in order to show her/him just the related patients and their personal data.

Finally, the entire system could be further extended, for example including additional languages or new test modules.

3.2 Core Components and Technology

The core system of our application is composed by (1) a web-service written on Ruby on Rails [14] and (2) an SQLite database [15]. The design of the application follows the MCV (Model Controller View) architecture, which keeps a clear separation between the core components of the system. Ruby on Rails is a way of programming that enforces MVC and allows a fast application development.

A graphical representation of the various web server application modules is illustrated in Figure 5. The examiner uses her/his browser to perform the test and sends results to the Web Server, that saves these data into the database. The web application controller takes the related parameters and computes the calculation of Z-score and error percentile, that are returned to the examiner's browser.

3.3 Database Models

The used database software library is SQLite, that implements a DBMS. The created database contains three models: Subject, Test and Parameter.

Subject. Represents the child that performs the test. This element has the following attributes: ID, Name, Surname, Sex, Date of Birth, Handedness, Class, Age, Evaluation Date.

Test. Represents the single experiment performed by a subject. Each test can have several sheets, which represent the sub-tests. For example, in Test 1 of reading section, each sheet is a list of words. The Test model has the following attributes: Test ID, Subject ID, Subject Class, Test Date, Test Code, Test Name, Sheet 1 Name, Sheet 1 Time, Sheet 1 Errors, Sheet 1 Z score, Sheet 1 Error Percentile, Sheet 2 Name, Sheet 2 Time, Sheet 2 Errors, Sheet 2 Z score, Sheet 2 Error Percentile, Sheet 3 Name, Sheet 3 Time, Sheet 3 Errors, Sheet 3 Z score, Sheet 3 Error Percentile, Sheet 4 Name, Sheet 4 Time, Sheet 4 Errors, Sheet 4 Z score, Sheet 4 Error Percentile, Total Time, Total Errors, Total Z score, Total Error Percentile.

Parameter. Represents the setting of values needed to calculate the Z-score and error percentile of each subject for a specific test. Since different tests use a different number of sheets, some attributes could be null for specific test records. The Parameter model contains the following attributes: Test Name, Sheet Name,

Class, Average Time, St. Dev. Time, Average Errors, Dev. St. Errors, Errors 90th percentile, Errors 95th percentile. Additional attributes are used only when parameters related to the total results are provided. These attributes are: Err. St. Time, Time 90th percentile, Time 95th percentile, Average Syll./Sec, St. Dev. Syll./Sec.

3.4 User Interface

3.4.1 Subjects View

The first page of our web application contains the list of all the subjects present in the database. Each subject has several links. The "Go at the Tests" link redirects to the experiment page of that subject, which contains the list of all done experiments and scores. The "Edit" link is provided to modify the subject information.

Finally, the "Delete" link is needed to remove the subject from the database. Figure 6 shows an example list of subjects, with their information and relative links, to show the tests, edit and delete each subject.

Above and below the subjects list, a link to insert a new subject is provided (not shown in the figure).

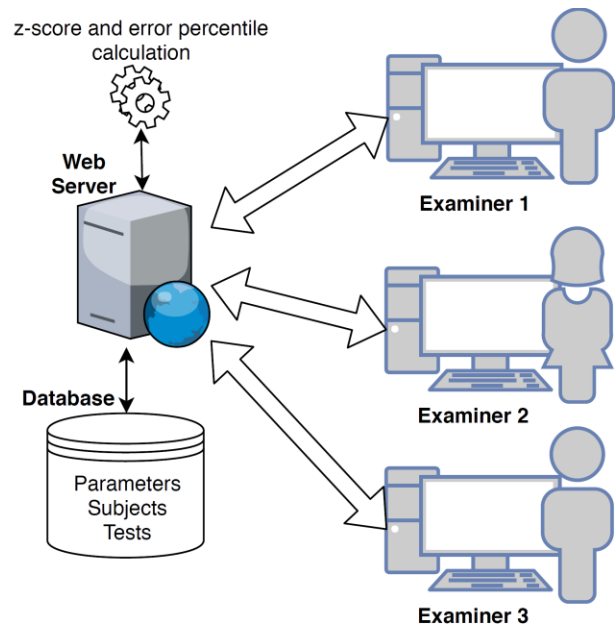


Figure 5: The framework of our web application and its modules.

ID	Name	Surname	Birth Date	Sex	Class			
10	Arianna	Derenno	2008-07-19	F	5	Go to the Test	Edit	Delete
11	Marco	Arezzo	2008-04-12	M	4	Go to the Test	Edit	Delete
13	Martina	Dumbolato	2010-04-05	F	3	Go to the Test	Edit	Delete
14	Stefano	Rampazzo	2011-01-29	M	3	Go to the Test	Edit	Delete
15	Riccardo	Colira	2010-02-05	M	3	Go to the Test	Edit	Delete
16	Giovanna	Salmaso	2010-11-17	F	5	Go to the Test	Edit	Delete
18	Sara	Bertoni	2000-02-07	F	2	Go to the Test	Edit	Delete

Figure 6: Example screen of subjects list

Figure 7: View of new reference parameters view form.

Lecture test: List of Words

Test done on July 22, 2018 at 13:40

Sheet	Time	Z-Score	Errors	Percentiles
List of Words 1	12	8.25	2	In the Standard
List of Words 2		Parameters not Available		
List of Words 3		Parameters not Available		
Total				

[Update Score](#) | [Restart Test](#)

Figure 8: An example of score table for Test 1: List of Words.

3.4.2 Reference Parameters View

The reference parameter module provides examiners with a convenient user interface that allows them to execute various class setup and management functions online.

The page contains all the parameters involved for the scores calculation. The parameters are used to correctly calculate the Z-score and error percentile based on the subject's time, errors number and scholar class. The parameters are substantially the average and standard deviation values of resulted time and errors from a set of tests performed in a group of 467 children.

In the same page, a button "New Parameter" leads to a form to enter a new set of values for a specific class, of a specific sheet, of a specific test (see Figure 7).

3.4.3 Subject Experiments View

When the user selects a subject, a new page is loaded, showing the subject information (name, surname, age, school class and handedness) and the related tests. The page content divides the tests into the two sections, reading and attention. Each category lists the name of the provided tests.

Figure 9: An example of reading word test form along with time and score fields.

The system provides indication of which test have been completed and which one has not yet administered: if a test has been completed by the examiner, it shows test date, measured time, and scores; if a the test is partially completed, meaning that a specific sheet is not administered, that sheet line shows an error information; if a test is completed but the parameters of the relative test, sheet and subject school class are not provided, the specific sheet line shows an error information. If a test has not been started, an indication of lack of the test is shown, with a related link to start it.

In Figure 8 an example of score table related to a subject is provided. For *Words List 1* all the data (subject results and parameters) exists to calculate the Z-score and error percentile. For *Words List 2* and *Words List 3* there is lack of the reference parameters. At the bottom of the table there are two links: "Update Score", to take any updated parameter and thus update the score, and "Restart Test", to restart the same test to the same subject.

3.4.4 Test View

When the examiner starts a test phase, the relative web page shows instructions, personal data of the subject and the effective test content. If a test involves several subtests, they are arranged in columns or rows. Each column contains the content that the subject has to read. At the bottom of the page, a fixed positioned chronometer (scrolling the page, the chronometer remains at fixed position on the browser) is provided with three buttons: start, end and reset. At the end of each column/row, there are two text field "Time" and "Errors". The test content elements are clickable in order to let the examiner to select and count the errors.

Below the columns a button to end the test is provided. When the examiner selects the end test button, the application performs the following actions:

1. it creates a new test record, storing time and errors of each performed sheet;
2. it calculates the Z-score and error percentile of each sheet and total sheets, if available;
3. it redirects to the subject page, showing a test related table, with all the results.

If a test involves several pages, when a subtest is ended, a link for the subsequent test is provided. The last page contains indeed the button to end the test.

In Figure 9, a reading word test is illustrated. It shows the words to be read, the number of committed errors and the two number fields, “Time” and “Errors”. Note the counter *Errors Committed*, having the utility to automatically count and take note of the errors by clicking on the single word.

4 Conclusion and Future Work

This work contributes to the reading and attentional disease evaluation by proposing a web application able to speed up the tests deployment and automatically giving the relative scores, based on several parameters. This application could improve the quality of work of examiners, that will only rely on this system to perform the assessments. The design and implementation of the web system for this scenario is just at the beginning of the study. We are going to improve the design of this web application in order to include new aspects and functionalities. For example, an account system could provide to clinicians an own workspace with own patients and tests.

Other improvements are related to host tests in other languages and to make sure that results accessible to all categories of users [16, 17].

Furthermore, we plan to integrate this web application with the serious game tools designed for the identification and treatment of DD [18, 19, 20].

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