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BEDA: a computerized assessment battery for dyslexia in adults

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Abstract

Dyslexia is a very common learning disability in Spanish-speaking university students and requires special attention by experts and teachers to intervene with and assist affected students during their learning process. However, appropriate tools that assess cognitive processes associated with dyslexia in adults do not exist in Spanish. In this context, a novel battery (BEDA) was built making use of web-based technology and based on multimodal communication to deliver assessment tasks using visual, auditory, and speech communication channels. BEDA has eight modules: six for assessing each cognitive process, one for analyzing results, and one for administration purposes. BEDA was tested by teachers and students at the University of Girona. The findings indicated that the teachers had a limited awareness of dyslexic students. However, they showed interest in using BEDA. The students were able to complete the battery in 40-50 minutes and their satisfaction was quite high in terms of usability.

Keywords: Computerized battery, BEDA, dyslexia, adults, university students, usability;

1. Introduction

Dyslexia or specific reading disabilities do not occur exclusively in children. The problem begins in childhood and persists into adulthood (Finucci, Gottfredson & Childs, 1986; Johnson & Blalock, 1987; Booth, Perfetti, Mac Whinney & Hunt, 2000; Wilson & Lesaux, 2001). People with this type of disability may experience difficulties during their academic careers, since reading is the basis of any educational process and has significant importance in every learning area. Furthermore, when we refer to reading as the basis of the educational process, we mean it not only in terms of academia but also the importance it has in every other activity of our lives. We access most of the information in our environment through written language. We are immersed in a so-called *information society* where activities (educational, economic, cultural, and others) are regulated through communication and information, so reading literacy is essential for the immersion and development of any individual in this society.

In many cases, although reading disabilities first appear in childhood, at university these kinds of difficulties persist with many students and this may affect their learning progress. Most university students have not been given a detection and assessment test to allow educational entities to identify dyslexia and specific difficulties that are associated with it (Jiménez, Gregg & Díaz, 2004; Sparks & Lovett, 2009). This work contributes to the design and development of dyslexia detection and assessment in adults, particularly in university students. In a previous work (Mejia, Diaz, Jimenez & Fabregat, 2011), we proposed a computerized assessment battery for dyslexia, called

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BEDA [*Batería de Evaluación de Dislexia en Adultos*], focus on assessing reading difficulties in Spanish, a language in which appropriate tools for assessing cognitive processes associated with dyslexia in adults do not exist (Jiménez, Gregg & Díaz, 2004). In this paper we present the development and testing of BEDA.

Reading assessment has traditionally been done by observing the precision or accuracy, the speed and the comprehension of the reader. Assessment, however, should also focus on the underlying cognitive processes involved in the reading process, since such an exhaustive evaluation provides information on reading behavior and data from those processes that are deficient. Knowing this information lets experts (psychologist, pedagogue, or counselor) make recommendations for the most suitable intervention and/or assistance for the dyslexia profile presented by a particular student.

BEDA is composed of 15 tasks that can be completed by students 16 years old and older. The BEDA tasks detect and verify if a student has reading disabilities and identify the associated cognitive processes that may be affected. Dyslexia detection and verification is the first essential step to intervening with and/or assisting affected students during their learning processes to minimize the negative impact associated with reading disabilities.

BEDA assesses the cognitive processes that have been empirically demonstrated may be present as deficits in adults with dyslexia (Bruck, 1993; Lachmann & van Leeuwen, 2008; Decker, 1989; Felton, Naylor & Wood, 1990) to identify specific cognitive difficulties in students. Thus, when students complete the BEDA tasks their cognitive process performances are stored to identify whether or not a difficulty is present and to prepare appropriate intervention and/or assistance.

In BEDA, student's cognitive processes are assessed by different tasks presented through web-based software. The responses to those these tasks (both responses with successes/errors and execution time for some tasks in which performance time is measured) are automatically compared with normative data considering the student's educational level; i.e., individual results are compared with the results of a population or group to which the student belongs. This requires the establishment of a reference level, which will done to obtain a rating after making the relevant statistical analysis when BEDA is administered to a representative sample of the population.

The cognitive processes assessed in BEDA are: phonological processing, orthographic processing, lexical access, processing speed, verbal working memory, and semantic processing. After BEDA is delivered, students may view and download the specific report detailing the score on each of the tasks and cognitive processes assessed, equating the score to their corresponding percentiles according to the scales set for the population of students.

This paper is structured as follows. In the second section we explain the modules that are part of BEDA and its implementation and testing. The third section describes a case study with a group of students and teachers from the University of Girona and University of La Laguna. Finally, the fourth section draws some conclusions and presents a discussion.

2. BEDA: Assessment Battery for Dyslexia in Adults

BEDA is a computer-assisted tool developed with web-based technology. It main objectives are to assess the cognitive processes that are deficient in students with dyslexia, and allow the students to review and analyze the results obtained. The design and the architecture of BEDA consists of eight modules: six for the assessment of each cognitive process involved, one for the analysis of results, and one for administration purposes.

2.1. Assessment modules

Assessment modules are independent modules designed to bring together the different assessment tasks for each cognitive process. These tasks have been designed based on multimodal communication that allows students to communicate with BEDA through different modes (visual, auditory, and speech) according to the specific objective of each assessment task. Hence, students are presented with different modes of interaction; some tasks ask them for instructions to follow (inputs) and others to deliver an answer (outputs). For input information the BEDA architecture includes: an automatic speech recognition system called Sphinx4 which converts human speech into individual words (Walker, Lamere, Kwok, Raj, et al, 2004), the insertion of written words and characters for specific commands by means of using the keyboard, and the selection of options using the mouse device. As output information BEDA gives students instructional information, support and guidance using output mechanisms such as text on screen, graphical representation, recorded audio and synthesized voice. The following paragraphs describe the six assessment modules in BEDA:

- The phonological processing module contains seven tasks that assess mental manipulation skill over the segments that belong to speech (phonemes, syllables and rhymes): 1) segmentation into syllables (Johnson & Blalock, 1987) requires segmentation into syllables of words which are delivered to the user aurally; 2) number of syllables (Johnson & Blalock, 1987) requires counting the number of syllables of aurally presented words; 3) segmentation into phonemes (Johnson & Blalock, 1987) requires separating aurally presented words in phonemes; 4) general rhyme (Johnson & Blalock, 1987) requires saying three words that rhyme with a word aurally delivered; 5) specific rhyme (Johnson & Blalock, 1987) requires comparing two pairs of words aurally presented and indicates whether they rhyme or not; 6) phonemic location (Vellutino & Scanlon, 1987) requires comparing two pairs of words aurally presented including a different sound and indicating whether the different sound is located at the beginning, middle or the end; and 7) omission of phonemes (Beringer, 1994) requires repeating one word presented aurally, and then repeating the word aurally omitting a segment from it.
- The orthographic processing module contains two tasks in which orthographic knowledge of words is assessed: 1) orthographic choice (Stanovich, & West, 1989), which requires choosing between two words presented visually the one that is properly written; and 2) homophone/pseudohomophone choice (Olson, Forsberg & Wise, 1994), which requires choosing, between two homophones presented visually, the one that is the answer to a question presented aurally.
- The lexical access module consists of two tasks, reading words (Guzmán & Jiménez, 2001) and reading pseudowords (De Vega, Carreiras, Gutiérrez & Alonso, 1990), where the user has to read out loud, precisely and quickly, words (or pseudowords) presented visually.
- The processing speed module contains one visual speed task (DeFries & Baker, 1983) that requires the user to select as quickly as possible groups of equal numbers and letters from a set of distractor groups.
- The verbal working memory module contains one memory task (Beringer, 1994), which visually presents a pseudoword for one second and then requires the user to write the entire pseudoword or just a part of it, according to the instructions presented aurally.
- The semantic processing module contains two text-reading tasks that assess reading comprehension. These tasks require the user to answer a list of questions per text.

In BEDA, the tasks are composed of different items (or exercises) that students must perform. Every task has an associated message explaining how to do it, and each item of a task has an associated stimulus to complete it (e.g., a word, a question, etc.). Moreover, every item has an associated solution that is used to determine whether or not the student has answered the stimuli correctly. In some cases, the item also has information about the audio of the stimuli, the number of syllables or phonemes of words related to the item, the dictionary and grammar used for the speech recognition system, and/or the syllabic structure, depending on whether the task involves it. Additionally, in every task some example items provide associated feedback in case the user is right or makes a mistake.

Student responses for each item of a task are automatically stored in a database according to the key pressed, the option clicked, the written word, or the word spoken by the student. The value of a response is: 1 (one) if the answer was correct or 0 (zero) if it was a mistake. Additionally, the responses in text, the recorded response, the execution time of each item and, in some cases, student reaction time to a stimulus are stored

2.2. Analysis of results and administration modules

The analysis of results module let delivers the students' results report after they have completed the assessment tasks. It automatically generates an individual report for each student with: 1) the student profile, 2) the scores obtained and the difficulty level (none, slight, moderate or severe) presented on each assessment task, 3) the identification of cognitive processes that are deficient and the specific difficulty level of them (none, slight, moderate or severe) according to the results of the assessment tasks used in each one, 4) the diagnosis of the presence or absence of dyslexia taking into account the criteria set, 5) overall cognitive performance obtained from the scores of the assessment tasks, and 6) a set of intervention and/or assistance recommendations for students based on their difficulty levels of each cognitive process. Moreover, the report explains in detail each of the cognitive processes assessed and interprets the students' scores, and specifies the processes that are more and less dominant for each student and the strong and weak points presented in assessment tasks.

To determine the difficulty level that is delivered to the student in each assessment task and cognitive process, the scores that the student obtained are automatically compared with normative data considering the student's educational level; i.e., individual results are compared with the results of a population or group to which the student belongs. This requires the establishment of reference levels or percentiles ranges, which will done to obtain a rating after making the relevant statistical analysis when BEDA is administered to a representative sample of the population.

On the other hand, the administration module is designed and implemented for the exclusive use of a subject matter expert (psychologist, pedagogue, or counselor). It allows the creation and/or edition of different assessment tasks, the creation and/or edition of reference levels for each assessment task, and the creation and/or edition of recommendations for intervention and/or assistance according to difficulty level presented in the assessment tasks.

2.3. BEDA Implementation

BEDA was implemented with standard technology and considering characteristics of reusability, interoperability, accessibility, and extensibility to make it easy to integrate with a learning management system (LMS). Moreover, BEDA was implemented using free and open source software such as Linux Operating System (specifically Ubuntu 9.04, with kernel version 2.6.28), Apache Web Server (version 2.0), Postgres (version 8.3.9), and PHP (version 5.2.6), due to their great popularity on different servers, their high performance, and their easy setup, configuration and acquisition. In terms of security, user authentication is based on the widely used reduction algorithm MD5, and permission levels are set by the developer according to the module the user wishes to enter. BEDA was also implemented using standard programming technologies that provide interoperability with other web-based systems such as interface based on XHTML and CSS, interactivity based on PHP and JavaScript, Java and Java Speech Library to implement functionalities related to the speech recognition system (sphinx4), and AJAX for asynchronous communication with the server via XML.

During the BEDA implementation we tested the different modules separately. These tests revealed the need for changes in the graphical user interface design and in the programming and structure of the task to achieve better system performance. The types of tests used were: connection to the database and proper storage of data, requirements, inspection programming and functional testing of the different modules. For the real-time tests (performance and usability) we followed the guidelines proposed in Sauro & Kindlund (2005), and designed a case study with a pilot group of students from the University of Girona and the University of La Laguna, as well as some volunteer teachers from University of Girona. This case study is presented in the next section. In terms of graphical user interfaces, BEDA was built with Moodle style patterms so that later it could be integrated with this LMS. BEDA delivers different interfaces for each type of user (student, teacher or expert) depending on the permissions and activities that can be developed. Figure 1 shows the graphical interface of menu cognitive processes that are assessed in the students, and Figure 2 shows the graphical interface of an assessment item of the general rhyme task to assess phonological processing.

3. Case Study: Performance and Usability

Nineteen students, all from the University of Girona or the University of La Laguna, participated in the case study: 9 men and 10 women with ages ranging from 18 years to 62 years (M=27.47, SD=9.125) and from different academic programs and levels (undergraduate and graduate). The aim of this case study was to evaluate the performance and usability of BEDA.

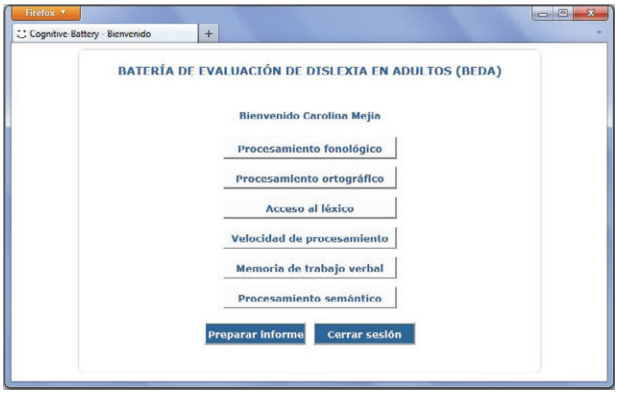

Figure1. Graphical interface of menu cognitive processes

Figure 2. Graphical interface of an assessment item

Most of the students completed the BEDA tasks at home, while others completed them in computer labs at their universities. In this survey the students answered questions about how well they understood each of the task instructions, the number of sessions they needed to complete all the tasks, if they performed the tasks in more than one attempt, and if they used some strategies or additional tools to complete the tasks. Moreover, in order to know how many were satisfied, students answered a series of questions (see Table 1) where they had to choose the most appropriate response on a scale of 1 to 5 based on their perception of the question. Finally, at the end of the survey a space was left where the students could write additional comments if they wished.

Table 1. Results of the survey filled in by students

Evaluation questions	M	SD	Satisfaction (%)
Was it easy for you to complete the tasks?	3.89	0.875	77.895
Were the instructions to perform the tasks clear?	3.74	1.046	74.737
Do you think it took a short time to complete the tasks?	2.74	0.933	74.737
Is the overall appearance of the elements of the battery (images, background colors, etc.) suitable?	3.89	1.100	77.895
How satisfied are you to complete the BEDA tasks using a web browser?	3.47	0.841	69.474
Was it easy to navigate through and locate the tasks in BEDA's graphical user interface?	4.47	0.697	89.474
Did BEDA adequately respond to your navigation pace?	3.84	1.119	76.842
In general, was BEDA intuitive (i.e., did it not require much effort and time to learn to handle it)?	4.26	0.991	85.263
Would you recommend this battery to other people or peers?	4.21	0.787	84.211

These results show that the satisfaction of students is quite high in terms of the usability of BEDA and the comprehensibility of the assessment tasks. Basically, students had difficulty understanding the audio instructions of some tasks and items, complying with BEDA's functional requirements (e.g., using an appropriate version of the browser, installing java when required, or setting the microphone), and repeating items that involve speech recognition, because students reported difficulties when receiving the feedback of some tasks that involve recording. Other findings were that students reported they needed an average of two sessions to complete the tasks without feeling tired, some students said they performed the tasks in only one attempt, and only two students reported using paper and pencil as a strategy to solve some of the tasks. Finally, the average time it took the students to complete the entire battery was between 40 and 50 minutes.

On the other hand, five teachers completed the BEDA tasks. Despite previously indicating that they had limited awareness of dyslexic students in their courses, after completing BEDA they said it was user friendly and intuitive and they expressed interest in knowing how they could use it in their classrooms. Moreover, teachers expressed curiosity about the student results and in knowing which teaching strategies could be used with affected students.

4. Conclusion and Discussion

According to the results obtained in the case study, BEDA was subsequently reviewed and restructured: audio instructions were again recorded in an appropriate setting, some items were modified by psychologists, help guides were incorporated, an automated functional requirement validation at the beginning of BEDA execution was introduced, and a module to verify the accuracy of the tasks using voice recognition was developed, since the acoustic model of the speech recognition software needs more training to improve the accuracy of voice recognition for all students. Considering that the results obtained were positive and the revision and restructuring process improved BEDA, we believe BEDA is prepared to be used on a sample of university students with and without reading disabilities in order to analyze its discriminate validity, and subsequently recover the scales of each assessment task to identify whether or not the student has a cognitive deficit and to confirm the dyslexia diagnosis. We also believe that using BEDA in a learning-teaching environment can be useful in terms of enabling students to know about their deficient cognitive processes and to know about strategies or recommendations they could follow to address these deficits. Furthermore, teachers may become aware of these disabilities and provide more appropriate learning resources for students who are affected.

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