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Revision articles

Information and Communication Technology (ICT) applied to dyslexia: literature review

Tecnologias da Informação e da Comunicação (TIC) aplicadas à dislexia: revisão de literatura

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ABSTRACT

The current paper aims to present an integrative literature review of scientific articles published in national and international journals, approaching the use of information and communication technology (ICT) such as computers, tablets, iPad's, mobile phones, e-readers, virtual reality and virtual learning environments, applied to dyslexia. The database consists of scientific articles published between 2010 and 2015, from the following platforms: Science Direct/Elsevier, SciELO - Scientific Electronic Library Online, MedLine - Medical Literature Analysis and Retrieval and Portal de Periódicos da CAPES. Scientific articles were selected, corresponding to 20 international (95.23%) papers and 1 national (4.77%) paper. The works considered in the present paper in general aim at the development and application of technological instruments that can minimize the difficulties by dyslexics in reading and writing learning. Due to shortage of articles published in Brazil, there is a need for more studies on this topic in view of the benefits of ICT within evaluation and intervention in dyslexia observed in international articles.

Keywords: Dyslexia; Technology; Software

RESUMO

O objetivo deste estudo é apresentar uma revisão integrativa da literatura, contemplando artigos científicos publicados em periódicos nacionais e internacionais que abordam o uso das tecnologias da informação e da comunicação (TIC), tais como computador, tablets, *iPads*, *mobile phones*, *e-readers*, realidade virtual e ambiente virtual de aprendizagem, aplicadas à dislexia. A base de dados escolhida para este estudo foi constituída de artigos científicos publicados no período de 2010 a 2015, a partir das seguintes bases eletrônicas de dados: *Science Direct/Elsevier*, *SciELO - Scientific Electronic Library Online*, *MedLine - Medical Literature Analysis and Retrieval* e o Portal de Periódicos da CAPES. Foram selecionados para este estudo 21 artigos científicos, sendo 20 (95,23%) artigos internacionais e um (4,77%) artigo nacional. Os trabalhos contemplados, no presente estudo, em geral, visam a construção e aplicação de instrumentos tecnológicos que possam vir a minimizar as dificuldades do disléxico no âmbito da aprendizagem da leitura e da escrita. Em meio à escassez de artigos publicados no Brasil, verifica-se a necessidade de mais estudos sobre essa temática, tendo em vista os benefícios das TIC no âmbito da avaliação e intervenção em dislexia constatados em artigos internacionais.

Descritores: Dislexia; Tecnologia; *Software*

INTRODUCTION

Dyslexia is a specific learning disorder of neurological origin, characterized by difficulties with correct reading fluency and with the decoding and spelling ability, resulting from a deficit in the phonological component of the language[1].

According to DSM-IV-TR[2], the reading performance of the dyslexic as measured by standardized tests is markedly below the expected level considering the chronological age, intelligence quotient (IQ) and school level specific to the individual's age.

The characteristics of reading – both silent and oral – in those individuals are marked by distortions, substitutions or omissions in which slowness and errors in comprehension predominate[2].

The use of technological tools opens up new possibilities for stimulating the development of reading skills in children[3]. In recent years, the contribution of technology in the field of special educational needs has been recognized. There is growing interest in the inclusion of individuals with learning difficulties – especially dyslexia – in the educational environment[4].

Technological resources have a positive effect on the performance of a reader's understanding[3]. Researchers have investigated the benefits of information technology to promote better reading skills[5-9] in dyslexics. In general, the results suggest that technological resources provide dyslexic individuals with better conditions for interaction and involvement in text reading and comprehension activities. The use of technological tools modernizes education, opening up more efficient teaching possibilities[9].

In some research[10-13] the benefits of using computers to assist the learning of reading in children with dyslexia and learning difficulties were found. Computer-assisted instruction[11] shows great promise regarding the work on reading skills in school, ranging from word knowledge to metacognitive reading strategies. In addition, learning environments that use technological tools can contribute to help students assume greater autonomy over academic contents[12].

This study aims to carry out an integrative review of the literature on information and communication technologies (ICT) applied to dyslexia, based on scientific studies published in the last five years.

METHODS

A search was made for national and international scientific articles dealing with the subject of information and communication technologies (ICT) applied to dyslexia in the electronic databases of Science Direct/Elsevier, SciELO - Scientific Electronic Library Online, MedLine - Medical Literature Analysis and Retrieval and the Portal of Periodicals of CAPES.

In all electronic pages of the databases, the advanced search engine was used, adopting the following descriptors in Portuguese and their correspondents in English to search for the articles: 'dislexia' (*dyslexia*), 'computador' (*computer*), 'tecnologia' (*technology*) and software. The descriptor 'dislexia' (dyslexia) was initially used in isolation and then combined with the other descriptors in all the databases searched. As inclusion criteria, we considered complete articles published in the English, Portuguese and Spanish languages, published between 2010 and 2015. We selected the papers that addressed the topic of ICT applied to dyslexia for this review, observed from reading titles and abstracts. We excluded from this review: repeated articles in the databases; studies in which the objective was purely informative about dyslexia; researches that used ICT, such as "electronic storybooks" and "digital games", in children without dyslexia; researches whose subjects presented intellectual deficiency, and articles that presented software to evaluate the reading of subjects without dyslexia.

In the initial phase of data collection, 41 complete papers were selected, of which 30 (73.17%) had been published in international journals and 11 (26.83%) in national journals. The articles were classified in ascending order by year of publication, highlighting the name of the journal, author(s) and objectives. Of the 41 studies, 20 international scientific articles and 1 national article were considered for this study, respecting the inclusion and exclusion criteria.

Data analysis consisted of the following steps: 1. distribution of articles published in international and national journals in which we found the subject 'ICT (information and communication technologies) applied to dyslexia' in the period 2010 to 2015 (Figure 1); 2. number of articles by journals in which the theme is observed, in the period from 2010 to 2015 (Figure 2); 3. number of scientific articles per year of publication, from 2010 to 2015 (Figure 3); 4. Distribution of scientific articles regarding the nature of the studies: Evaluation (E), Intervention (I) or Literature review (LR) (Figure 4); and 5. Characterization of the researches on the subject 'Information and Communication Technologies applied to dyslexia' in the period from 2010 to 2015 (Figure 5).

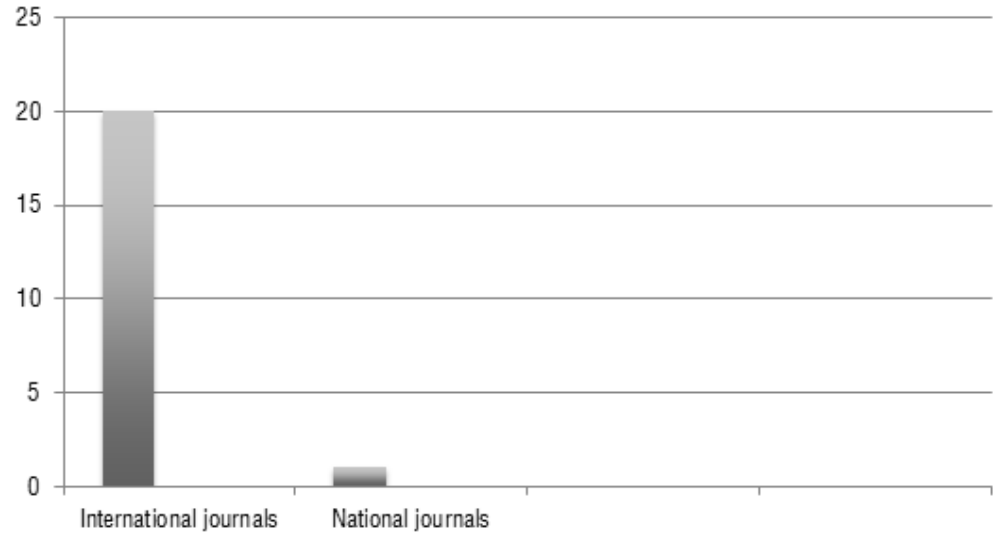

Figure 1. Distribution of articles published in international and national journals where it is observed the subject ICT (information and communication technologies) applied to dyslexia in the period 2010 to 2015

Journals	Number of articles
Annals of Dyslexia	1
Support for Learning	1
Computers and Education	2
DYSLEXIA	1
Escritos de Psicologia	1
International Journal of Education and Information Technologies	2
Journal of Computer Assisted Learning	1
Journal of Research in Special Needs	1
Multimedia Tools and Applications	1
Procedia Social and Behavior Science	3
Procedia Computer Center	3
Psico-USF	1
Plos One	1
The Journal of Academic Librarianship	11
Themes in Science & Technology Education	1
Total	21

Figure 2. Number of articles by journals where there is the theme ICT (information and communication technologies) applied to dyslexia, from 2010 to 2015

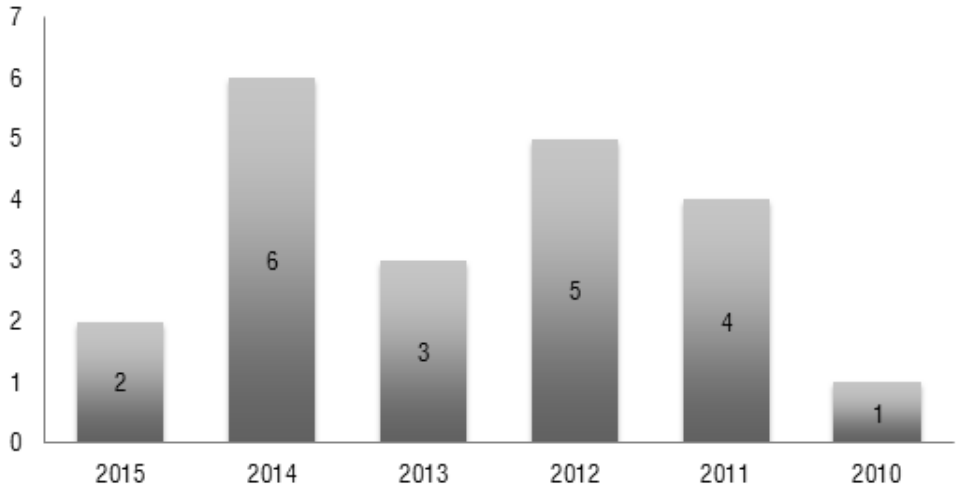

Figure 3. Number of scientific articles per year of publication, from 2010 to 2015

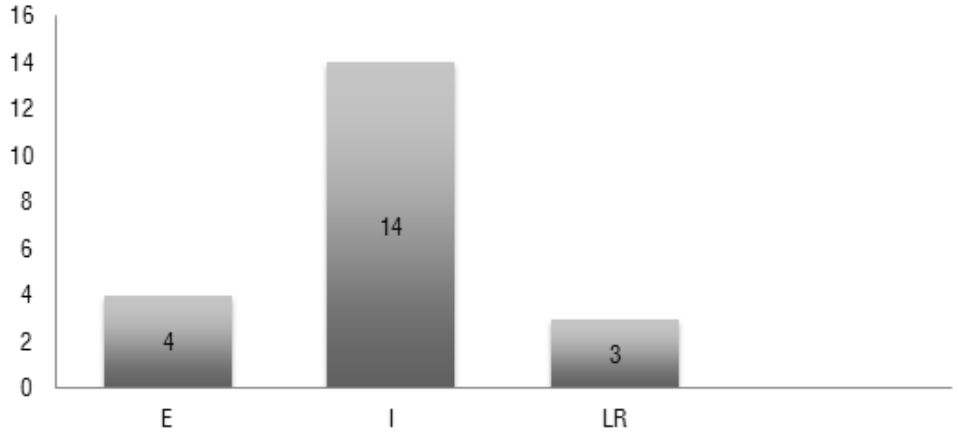

Figure 4. Distribution of scientific articles regarding the nature of the studies: Evaluation (E), Intervention (I) or Literature review (LR)

Title	Author(s)	Study description	Classification regarding the nature of the study: Evaluation (E), Intervention (I) and Literature Review (LR)	Journal	Year
Evaluation of a computerized program for phonic intervention in developmental dyslexia	Darlene Oliveira, Katerine Kukasova e Elizeu Coutinho de Macedo	This study verified the effectiveness of a software to promote phonological awareness.	I	Psico-USF	2010
Dyslexic students: success factors for support in a learning environment	Maria Bjorklund	This article examined success factors in the development of tools for dyslexics.	LR	The Journal of Academic Librarianship	2011
Laptops meets schools, one-one draw: m-learning for secondary students with literacy difficulties	Paul Conway e Jessica Amberson	The objective of this research was to investigate the use of laptops for children with learning difficulties, including dyslexia.	I	Support for Learning	2011
Computer-based learning of spelling skills in children with and without dyslexia	Monika Kast, Gian-Marco Baschera, Markus Gross, Lutz Jäncke e Martin Meyer	This study proposed a software to work with the spelling dyslexics and non-dyslexics.	I	Annals of Dyslexia	2011
Mejorar la fluidez lectora en dyslexia: diseno de un programa de intervención en espanol	Esther Gómez Zapata, Sylvia Defior e Francisca Serrano	This article presented an intervention program to work on the reading of children with dyslexia.	I	Escritos de Psicología	2011
Interactive multimedia learning object (IMLO) for dyslexic children	Masoumeh Sadat Abtahi	This research aimed at the development of a multimedia instrument to evaluate dyslexic children.	E	Procedia Social and Behavioral Sciences	2012
Dyslexic students in higher education and virtual learning environments: an exploratory study	Laurence Habib, Gerd Berget, Eika Frode, Norun Sanderson, Pia Kahn, Siri Fagernes e Anita Olcay	This paper presented results of the use of virtual learning environments (VLEs) with dyslexics.	I	Journal of Computer Assisted Learning	2012
Memory performance of dyslexic adults in virtual environments	Katerina Kalyvioti e Tassos Mikropoulos	This study tested tasks with the use of virtual reality in dyslexics.	I	Procedia Computer Science	2012
Multimedia elements as instructions for dyslexic children	Fadilahwati Abdul Rahman, Fattawi Mokhtar, Nor Aziah Alias e Ronaldi Saleh	The objective of this research was to evaluate technological tools for dyslexic children.	E	International Journal of Education and Information Technologies	2012
Learner needs analysis for mobile learning comic application among dyslexic children	Ronaldi Saleh e Nor Aziah Alias	This study evaluated the functionality of a mobile application for dyslexic children.	E	International Journal of Education and Information Technologies	2012
Dyslexia and early intervention: what did we learn from the dutch dyslexia programme?	Aryan van der Leij	This work presented results of an early intervention program in dyslexics.	I	DYSLEXIA	2013
Expanding horizons for students with dyslexia in the 21st century: universal design and mobile technology	Gavin Reid, Iva Strnadová e Therese Cumming	The aim of this study was to investigate the most appropriate technological resources to work with dyslexics.	LR	Journal of Research in Special Educational Needs	2013
E-readers are more effective than paper for some with dyslexia	Matthew H. Schneps, Jenny M. Thomson, Chen Chen, Gerhard Sonnert e Marc Pomplun	This research presented results of the use of e-readers with dyslexics.	I	Plos One	2013

Title	Author(s)	Study description	Classification regarding the nature of the study: Evaluation (E), Intervention (I) and Literature Review (LR)	Journal	Year
E-teacher in inclusive e-education for students with specific learning desabilities	Dragana Bjekic, Svetlana Obradovi, Milica Vueti e Milevica Bojovi	In this research, concepts of e-learning and e-teaching were used in children with dyslexia.	I	Procedia Social and Behavioral Sciences	2014
Virtual enviroments and dyslexia: a literature review.	Katerina Kalyvioti e Tassos A. Mikropoulos	This study proposed a review of the scientific productions on the use of virtual reality in dyslexia.	LR	Procedia Computer Science	2014
Promoting reading comprehension with the use of technology	Larysa V. Lysenko e Philip C. Abrami	This article presented the impact of two digital tools in the learning process of dyslexics.	I	Computers & Education	2014
APADYT: a multimedia application for SEN learners	Gonzalo Rubio, Elena Navarro e Francisco Montero	This research presented an application to assist teachers and parents of children with special needs and dyslexia.	I	Multimedia Tools and Applications	2014
EasyLexia: a mobile application for children with learning difficulties	Roxani Skiada, Eva Soroniati, Anna Gardeli e Dimitrios Zissis	The objective of this research was to develop a mobile application to work on reading, spelling and math with dyslexics.	I	Procedia Computer Center	2014
EasyLexia 2.0: redesigning our mobile application for children with learning difficulties	Roxani Skiada, Eva Soroniati, Anna Gardeli e Dimitrios Zissis	In this work a tablet game was presented for children with learning difficulties, such as dyslexia.	I	Themes in Science & Technology Education	2014
The possibilities of ICT use for compensation of difficulties with reading in pupils with dyslexia	Pavel Zikl, Iva Košek Bartošová, Katerìna Josefová Víšková, Klára Havlíčková, Alice Kučírková, Jolana Navrátilová e Barbora Zetková	The purpose of this article was to evaluate the use of ICT in reading tasks of dyslexics through the use of different sources, such as OpenDyslexic.	E	Procedia Social and Behavioral Sciences	2014
Computer instruction in handwriting, spelling, and composing for students with specific learning disabilities in grades 4-9	Virginia W. Berninger, William Nagy, Steve Tanimoto, Rob Thompson e Robert D. Abbott	This study investigated the benefits of using iPads to work on calligraphy, spelling and phrase writing in children with learning disabilities.	I	Computers & Education	2015

Figure 5. Characterization of the research on the subject of ICT (Information and Communication Technologies) applied to dyslexia in the period from 2010 to 2015

LITERATURE REVIEW

The analysis of the results considered 21 scientific papers, being 20 (95.23%) international and 1 (4.77%) national (Figure 1). The 21 articles surveyed were published in the following countries: seven in the United States, seven in the Netherlands, two in the United Kingdom, two in England, one in Spain, one in Greece and one in Brazil.

From those findings, it can be suggested that national publications on ICT applied to dyslexia are still scarce. Some scholars[5] believe that these surveys provide insight into which approaches and technologies are best suited to assist children with learning difficulties. The use of ICT in education seems to provide more interactive experiences, which can motivate children at an early age, attenuating the impacts of their own difficulties in the daily practice of reading and writing[7].

As shown in Figure 2, the 21 scientific papers selected for the study were published in 14 international journals and one national journal.

Figure 3 shows the distribution of articles according to the year of publication, where it is possible to verify a higher concentration of publications in the years 2012 and 2014. Some studies on ICT applied to dyslexia[14-17] verified the applicability of interactive multimedia tools in dyslexic subjects and suggestions for future work. The functionality of software in other technological instruments, such as tablets, has been tested with adaptations to improve the performance of dyslexic children[18].

The scientific articles selected for this research were distributed according to the nature of the study (Figure 4). They were classified in: Evaluation (E) - research where the evaluation of the applicability of ICT in dyslexic subjects is observed; Intervention (I) - research where ICT intervention is observed in subjects; Literature Review (LR) - where we observe studies that carried out a theoretical survey on ICTs applied to dyslexia.

In the four (19.05%) articles classified as being of evaluation (E) it was found that the information collected in questionnaires applied to teachers and/or parents allowed modifying and/or adapting the construction of technological products for children with dyslexia[9,14,16,19].

In a study classified as being of evaluation[19], in addition to describing the functions of multimedia tools in the construction of technological products for dyslexic children, a concern was observed to identify the impression that children and teachers have about the use of ICT in learning to read and write.

The influence of letter font choice on reading materials for children with specific learning difficulties was described in a study[9] with 150 children. The results presented reveal the benefits of an adequate choice of font in terms of speed and reading errors. The *OpenDyslexic font*[20] was created for dyslexics and has shown satisfactory results in reading tests.

The studies classified as intervention (I) of ICT applied to dyslexia accounted for 66.67% of the 21 scientific papers analyzed. It was seen that one of the recently published works in this category[18] suggested interface design options for building a tablet game for children with learning difficulties. EasyLexia 2.0[18] was developed from software tested on mobile phones, composed by activities of spelling, memory and mathematical problems for children with dyslexia[7].

In an Intervention research conducted with dyslexic children[21], phonological and morphological activities were associated with computer use, with positive effects on reading speed and orthographic skills when used early. It was also highlighted that the use of ICT can be useful in the early intervention of children with risk characteristics for learning disabilities.

In the studies that described the use of software[3,5,8,10,11,13,17] and e-readers[22], the effectiveness of technological tools to promote better reading performance in dyslexics was verified.

In a recent scientific article[3], the effectiveness of pedagogical activities on iPads was investigated, increasing the applicability for children with other specific learning difficulties, such as Dysgraphia - specific disorder in writing graphemes.

In the results of the application of two technological instruments - Abracadabra (ABRA)[5] and e-Pearl[5] - benefits in letter-sound recognition, phonological awareness and reading comprehension have been described, also showing positive results in the case of children with poor attention and low reading performance. Children systematically submitted to the programs presented learning gains in the written language and better performance in the metacognitive reading skills.

In a study carried out with dyslexic children[8] a computerized intervention program was described, structured with metaphonological activities of reading syllables, words and texts to promote better levels of reading fluency and reading comprehension. The use of the software allowed recording the successes

and mistakes of the activities, and the execution time. For each child a table was generated to analyse their evolution and possible gains in the different levels: syllables, words and texts.

One study carried out with children with literacy difficulties, including dyslexia, presented positive results from the use of tablets to support reading and writing activities at school[10].

The results of the use of software with phonological and multisensory resources, such as sound-letter correspondence and auditory strategies, were presented in a study with children with and without dyslexia[11], showing significant benefits in the orthographic performance of dyslexic children.

In an intervention study that aimed to promote phonological awareness and grapheophonemic correspondences in dyslexics using the Computerized Phonics Alphabetization software[13], it was concluded that dyslexic children submitted to intervention sessions presented benefits in reading and writing skills, besides significant decrease in the execution time of the tests.

One intervention study described the use of a pedagogical application, APADYT[17], aimed at assisting the pedagogical work of parents and teachers of children with special educational needs, such as dyslexia, dysgraphia, dyscalculia, attention deficit and/or hyperactivity disorder (ADHD) and cross laterality.

A study on the use of e-readers[22] with children with dyslexia concluded that for some dyslexics the e-reader as a technological tool facilitates reading and comprehension when compared to reading on paper. In e-readers it is possible to have a larger font of letters, fewer words per line, greater spacing between lines, and control of screen brightness. On the other hand, in a study on the use of virtual learning environments (AVAs)[23], with dyslexic undergraduate students, some preference for paper text was identified through interviews. Some dyslexics preferred to read the text on paper because it was easier to mark the important passages. In addition, in writing, they considered that the keyboard reduced writing speed. Others, however, relied on the word processor for offering the spell checker tools and verifying grammatical errors, as they would not be able to perceive the errors alone. The text-to-speech conversion was commented by some interviewees as being a useful tool for perceiving the errors of a text, written by themselves.

The use of virtual reality technologies was described in a research that aimed to evaluate the operational memory of dyslexic graduate students[24]. It concluded that virtual reality can be an effective technological evaluation tool, even to be used in early memory tests in children.

When the subject concerns speech therapy with remediation and phonological intervention objectives, the performance of dyslexic children submitted to the intervention program associated with computer use regarding reading skills was highlighted, providing an increase in reading and spelling levels of dyslexic children[25].

A literature review paper[12] on support for dyslexic students – based on the research on eight online databases – emphasized that it is important to recognize the individual needs of students so that technical solutions can be adapted.

The relationship between virtual environment and dyslexia has been described in a literature review[15] and it verified that scientific articles published so far presented benefits and orientations for parents, teachers and professionals of dyslexic individuals.

In a review paper on the use of mobile technologies[25] – including smartphones, iPods, tablets and laptops to assist students with dyslexia – it was found that, although useful, they do not replace traditional teaching and learning strategies that have scientific evidence to support them.

In the 21 related scientific articles[3,5-19,21-25] published between 2010 and 2015, some aspects regarding the use of ICTs applied to dyslexia were suggested: type and font size; more suitable color variations in the screens that favor reading; control in the time of execution of the activities; text-to-speech conversion to be able to listen to the read text itself; phonological and multisensory resources to stimulate phonological awareness and spelling, besides interactive multimedia instruments as well as more appropriate characteristics of technology.

The distribution of the bibliographic references presented in this literature review on ICT applied to dyslexia can be observed in Figure 5.

CONCLUSION

This work presented an integrative review of the literature on information and communication technologies (ICT) applied to dyslexia. The articles included in this study presented interesting alternatives for the evaluation and intervention in dyslexia, among which we can mention: tools for reading evaluation and comprehension of texts, softwares and e-readers used to promote better reading performance in dyslexics,

virtual environments and multimedia resources. It is observed that the published works, in general, aim at the construction and application of technological instruments that may facilitate the performance of the dyslexic in the learning of reading and writing. In the midst of the shortage of articles published in Brazil – when compared to the number of international articles – there is a need for further studies on this topic, considering the benefits of ICT in the scope of dyslexia assessment and intervention.

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