

Neuroanatomical and linguistic characteristics of acquired dyslexia

Características neuroanatômicas e linguísticas na dislexia adquirida

Características neuroatômicas y lingüísticas en la dyslexia adquirida

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Abstract

Introduction: acquired dyslexia is characterized by the loss of the capacity to understand the meaning of written words previously developed. This condition can be caused by strokes, trauma and other brain diseases. **Objective:** to investigate the characteristics of acquired dyslexia, exploring the neuroanatomical correlations in the encephalopathies that produce them, through a literature review. **Method:** For the study, the authors followed the criteria suggested by the Cochrane Handbook. Firstly, a question was asked, followed by the location and careful selection of the articles. Then, the critical evaluation of each study occurred, ending with the analysis, interpretation and presentation of the results found. The databases Science Direct, Pubmed / Medline and Scopus, using the descriptors “brain diseases”, “brain injuries”, “traumatic brain injuries” and “stroke” with the Boolean operator OR, associated with the descriptors “alexia” and “acquired dyslexia” through the Boolean operator AND. **Literature Review:** The first electronic search counted 137 scientific articles, of which 11 were chosen because they were studies containing the anatomical relationship of lesions and/or clinical and linguistic signs of acquired dyslexia. **Conclusion:** The main cause of acquired dyslexia was stroke, especially in the occipital lobe, in both hemispheres, affecting the perception and subsequent visual recognition of the word. It is necessary to broaden the research on acquired dyslexia in order to deepen the knowledge about it, instrumentalizing the clinicians for the rehabilitation process

Keywords: Acquired dyslexia; Language Disorders; Stroke; Traumatic Brain Injuries

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Authors' contributions:

BNP Design of the study; Methodology; Data collection; Guidance. UFB Methodology; Data collection; Critical review. MRV Data collection; Critical review

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Resumo

Introdução: a dislexia adquirida caracteriza-se pela perda da capacidade de compreender o significado de palavras escritas desenvolvida previamente. Esta afecção pode ter origem em acidentes vasculares, traumatismos e outras doenças cerebrais. **Objetivo:** investigar as características da dislexia adquirida, explorando as correlações neuroanatômicas nas encefalopatias que as produzem, por meio de uma revisão de literatura. **Método:** Para a realização do estudo, os autores seguiram os critérios sugeridos pela Cochrane Handbook. Primeiramente, formulou-se uma pergunta, seguida da localização e seleção criteriosa dos artigos. Em seguida, ocorreu a avaliação crítica de cada estudo, finalizando com a análise, interpretação e apresentação dos resultados encontrados. Foram consultadas as bases de dados Science Direct, Pubmed/Medline e Scopus, com a utilização dos descritores “brain diseases”, “brain injuries”, “traumatic brain injuries” e “stroke” com o operador booleano OR, associado aos descritores “alexia” e “acquired dyslexia” por meio do operador booleano AND. **Revisão de Literatura:** A primeira busca eletrônica contabilizou 137 artigos científicos, dos quais 11 foram eleitos por se tratar de estudos contendo a relação anatômica das lesões e/ou sinais clínicos e linguísticos da dislexia adquirida. **Conclusão:** A principal causa da dislexia adquirida foi o acidente vascular cerebral, sobretudo no lobo occipital, em ambos os hemisférios, repercutindo na percepção e, posteriormente, no reconhecimento visual da palavra. Faz-se necessário ampliar as pesquisas sobre a dislexia adquirida, a fim de aprofundar o conhecimento sobre a mesma, instrumentalizando os clínicos para o processo de reabilitação.

Palavras-chave: Dislexia adquirida; Transtornos da Linguagem; Acidente Vascular Cerebral; Lesões Encefálicas Traumáticas

Resumen

Introducción: la dislexia adquirida se caracteriza por la pérdida de la capacidad en comprender el significado de palabras escritas desarrollada previamente. Esta afección puede originarse en accidentes vasculares, traumatismos y otras enfermedades cerebrales. **Objetivo:** investigar las características de la dislexia adquirida, explorando las correlaciones neuroanatômicas en las encefalopatías que las producen, por medio de una revisión de literatura. **Metodos:** Para la realización del estudio, los autores siguieron los criterios sugeridos por la Cochrane Handbook. Primero, se formuló una pregunta, seguida de la localización y selección criteriosa de los artículos. A continuación, ocurrió la evaluación crítica de cada estudio, finalizando con el análisis, interpretación y presentación de los resultados encontrados. Se han consultado las bases de datos Science Direct, Pubmed / Medline y Scopus, con la utilización de los descriptores “brain diseases”, “brain cura”, “traumatismo cerebrovascular” y “stroke” con el operador booleano OR, asociado a los descriptores “alexia” y “adquirido dyslexia” a través del operador booleano AND. **Revisión de Literatura:** La primera búsqueda electrónica contabilizó 137 artículos científicos, de los cuales 11 fueron elegidos por tratarse de estudios que contenían la relación anatómica de las lesiones y/o signos clínicos y lingüísticos de la dislexia adquirida. **Conclusión:** La principal causa de la dislexia adquirida fue el accidente cerebrovascular, sobre todo en el lobo occipital, en ambos hemisferios, repercutiendo en la percepción y posterior reconocimiento visual de la palabra. Se hace necesario ampliar las investigaciones sobre la dislexia adquirida, a fin de profundizar el conocimiento sobre la misma, instrumentalizando a los clínicos para el proceso de rehabilitación.

Palabras claves: Dislexia adquirida; Trastornos del Lenguaje; Accidente cerebrovascular; Lesiones Traumáticas del Encéfalo

Introduction

Reading and writing are activities whose acquisition is among the most significant of the human mind and most required in modern societies¹. The domain of writing grants rights and citizenship to those who handle their tools competently².

Among the processes that promote the complex activity demanded in reading are emphasized the identification of letters, word recognition, access to meaning, syntactic and semantic integration³.

Competence in reading, with the extraction of information from a text, can only be achieved if there is both word recognition and access to the meaning of these words, individually and in the specific context⁴.

When the reading effects, defined as the advantage that the characteristics of the stimuli produce in the accuracy and/or time of their processing are altered, they affect the reading of both children in the acquisition phase and in individuals after lesions⁵.

According to the DMS-5, Dyslexia is an alternative term used in reference to a pattern of learning difficulties characterized by problems in accurate or fluent word recognition, decoding problems and spelling difficulties⁶, preventing the fluency and understanding of the text⁷. It is a Specific Learning Disorder divided by area of difficulty, in this case, with impairment in reading⁶. It is a condition defined as a performance below expectations when compared to other cognitive profiles of the child, even when neurological and sensory aspects are normal and socioeconomic factors, including access to education, are adequate⁸. This condition reveals problems in the acquisition of reading and writing from the beginning of their learning and significantly interferes with academic success or activities of daily living that require reading skills⁶⁻⁹.

From a neurobiological perspective, the change in reading skills can also be classified based on the cause: i) primary or genetic, of hereditary characteristic; ii) secondary or development, when hormonal, nutritional, socioenvironmental; iii) late or acquired, caused by brain injuries.

The investigations of acquired dyslexia began in the late nineteenth century, with Dejerine (1891) reporting on two patients with reading and writing deficits, after an infarction involving the left parietal lobe. Dejerine attributed the disturbance to a rupture of the “optical image of words,” which he

believed to be supported by the left angular gyrus. Anticipating some contemporary psychological accounts, he concluded that reading and writing required the activation of these “optical images” and that their loss resulted in the inability to recognize or write even familiar words¹⁰.

The acquired dyslexia, officially included in the Health Descriptors in 2012, is characterized by the loss of the capacity, previously developed, to understand the meaning of written words. This condition may originate from vascular accidents, trauma and other brain diseases⁹.

Acquired dyslexia can still be classified as peripheral or central. Peripheral dyslexia occurs mainly due to visual problems, such as in cases of visual field neglect or changes in focus maintenance¹¹. Central dyslexias form a cluster of disorders in which the processes result in difficulties that affect the comprehension and/or expression of written words⁹. It can be caused by a change in the semantic reading resulting, for example, from dementias, or difficulties in sublexical processing and impairments in the processes of recognition of whole words. When both the lexical and semantic skills are altered, there is a clinical condition of profound dyslexia¹²⁻¹³.

Alexia (inability to read) and agraphia (inability to write) may appear associated or not with aphasia (language disorder), depending on the location of the lesion. Some researchers believe due to the recent emergence of writing and much more from the literacy culture of a large part of population (less than a century), it is unlikely that a specialized reading system has developed in the human brain in a short evolutionary period. Therefore, alexia without aphasia could not be attributed to a impairment in this supposed special reading system, but rather caused by disconnection between the visual and the language system¹⁴.

Reading disorders are often found in patients with acquired brain lesions because, given the complexity of the activities involved in reading, many regions of the brain are recruited so that the subject is able to identify the graphemes, understand the message and memorize, thus requiring, the maturation and functional preservation of these regions¹⁴.

There is a growing literature on dyslexia, however, they refer, especially in Brazil, to specific learning disorders. Therefore, the objective of this review was to investigate the characteristics of acquired dyslexia, exploring the neuroanatomical

correlations in the encephalopathies that produce them.

Methods

This research is a systematic review of the literature, descriptive and exploratory, without meta-analysis, following the precepts established by the Cochrane Handbook¹⁵. In this study, we try to transform information from basic studies into scientific applicability, enabling healthcare professionals to better clarify theoretical issues in favor of clinical practice.

Initially, the following question was elaborated for the bibliographic review: "Which brain regions affected in alexia and acquired dyslexia?". The review was based on the online search of studies published in English, in the last five years, in the databases such as Science Direct, Pubmed/Medline and Scopus. As descriptors of the search, the following terms were used according to the DeCS system: brain diseases, brain injuries, traumatic brain injuries and stroke with the Boolean operator OR, associated to the descriptors alexia and acquired dyslexia by the boolean operator AND. The search period in the databases was in the month of May, 2018.

The selection of papers was carried out by two researchers, independently and blindly. The third

researcher acted as a reviewer consulted in cases of non-agreement between the peers. The eligibility criteria of the papers selected from the descriptors were: a) clinical studies; b) population of adolescents and adults; c) scientific papers published in the last five years; d) complete scientific papers in English. The papers replicated in the databases were considered only once.

In the first stage of selection were read title and abstract in order to verify consonance with the proposed theme. Of these, they were pre-selected for reading in full and analyzed according to the eligibility criteria. The selected papers were analyzed according to the following categories: objective of study; type of study; methods of assessing acquired dyslexia or neurological disorders; main observed conditions; characteristics in the language field; association between encephalopathies and acquired dyslexia; characteristics of the study population; authors, year of publication and country where the study was developed.

Literature review

A total of 137 papers were found, among which were excluded those with more than five years of publication or duplicates, revisions and those that did not fulfill the eligibility criteria (Table 1).

Table 1. Selection process of papers for review.

| Database | Nº papers | Last 5 years | Selected papers |
|----------------|-----------|--------------|-----------------|
| Pubmed | 63 | 18 | 11 |
| Scopus | 57 | 17 | |
| Science Direct | 17 | 5 | |

Among the papers selected, six (54.5%) deal with studies or series of cases (between one and nine subjects). In ten papers (90.9%), vascular accidents caused dyslexia and in one (9.1%), only TBI (Table 2).

Regarding the location of the lesions, nine studies (81.8%) cite the posterior regions, occipital lobe or posterior cerebral artery (PCA) of which six (67%) on the left side, two (22%) right side and one (11%) in both hemispheres. (Table 3).

Table 2. Classification of papers selected by author, year and country of publication, type of study, objectives, sample and procedures used.

| Authors, year, country | Type of study | Objective | Sample | Procedures |
|--|---------------|---|--|---|
| Rupareliya, Naqvi, Hejazi 2017 EUA ¹⁶ | Case study | To describe a case of alexia without agraphia after stroke | Man 72 years old | Angiography by Computed Tomography and Magnetic Resonance Imaging |
| Petersen Vangkilde Fabricius Iversen, Delfi, Starrfelt, 2016 Dinamarca ¹⁷ | Control case | To characterize the visual processing speed and the period of apprehension after posterior stroke | subjects with unilateral lesions | Perimetry, single word reading |
| Robinson, Collins, Mukhy, Beeson 2016 EUA ¹⁸ | Case study | To describe a case of alexia without agraphia due to stroke in the right occipital lobe | Man, 65 years old | Neuropsychological assessment |
| Kim, Rising Rapcsak, Beeson, 2015 EUA ¹⁹ | Case series | To examine the therapeutic effects of a combined stroke treatment | 3 subjects with altered reading after stroke | The combined treatment for reading speed and spelling |
| Cuomo, Flaster, Biller 2014 EUA ²⁰ | Case study | To describe a case of alexia without agraphia due to stroke | Woman, 40 years old | Echoplanar axial diffusion-weighted MRI (DWI) e Catheter cerebral angiogram |
| Gandhi, Gillihan, Wozniak, Zhuo 2014 EUA ²¹ | Case study | To analyze a case of Wallerian degeneration of the corpus callosum associated with alexia without agraphia | Man, 69 years old | Computed tomography |
| Kraft, Grimsen, Kehrer, Bahnemann, Spang, Prass et al. 2014 Alemanha ²² | Observational | To describe the neurological and neuropsychological deficits after myocardial infarction | 128 subjects with ischemic cerebral infarction | neurophthalmologic and neuropsychological tests |
| Sharma, Handa, Prakash, Nagpal K, Bhana, Gupta et al 2014 Índia ²³ | Case study | To analyze a case of alexia without agraphia after stroke of the posterior cerebral artery | Man, 55 years old | Neurological examination and language test |
| Sohlberg, Griffiths, Fickas 2014 EUA ²⁴ | Transversal | To analyze reading problems in subjects with TBI with mild to moderate cognitive impairments and as a strategy of reading comprehension in digital texts. | 15 adults with TBI and 15 in the control group | Two tasks of comprehension: a task of verification and a free recall task. |
| Galleta, Campanelli, Maul, Barrett, 2014/EUA ²⁵ | Transversal | To assess neglected dyslexia with functional reading materials | 67 survivors of stroke | Tests for spatial neglect, tests for neglect dyslexia (words, sentences, papers e menu) |
| Beschin Cisari, Cubelli, Della Sala et al., 2014 ²⁶ | Transversal | To analyze reading in prose in individuals with symptoms of spatial neglect | 30 stroke survivors | General neuropsychological examination, evaluation of unilateral spatial neglect, reading tasks (prose, one- and two-column text) |

Legend: stroke; TBI - Traumatic Brain Injury

Table 3. Referred condition and affected brain location in the subjects of the selected studies.

| Author | Observed conditions | Lesion local |
|--|---|--|
| Rupareliya, Naqvi, Hejazi ¹⁶ | Alexia without agraphia with homonymous right hemianopia | Left occipital lobe, extending to the corpus callosal splenium and posterior thalamus |
| Petersen Vangkilde Fabricius Iversen, Delfi, Starrfelt ¹⁷ | Reductions in the visual extension contralateral to the lesion, and four patients presented bilateral reductions. Six patients presented selective deficits in visual extension | Posterior cerebral artery (right and left) |
| Robinson, Collins, Mukhy ¹⁸ | Reading deficit without visual alteration, with ability to write, isolated words and small sentences, intact | Right occipital lobe |
| Kim, Rising Rapsak, Beeson ¹⁹ | After treatment the subjects showed a higher reading speed and better accuracy in reading isolated words (pp irregular words) and reading rates | Posterior cerebral artery with damage to left ventral occipitotemporal region |
| Cuomo, Flaster, Biller ²⁰ | Alexia without agraphia | Left visual cortex and corpus callosal splenium (left ACP occlusion and right ACP constrictions and dilatations) |
| Gandhi, Gillihan, Wozniak, Zhuo ²¹ | Alexia without agraphia | Left occipital lobes and association fibers between the visual cortex and the left angular gyrus |
| Kraft, Grimsen, Kehrner, Bahnmann, Spang, Prass et al ²² | 52.3% visual field deficits, reading 45.3%, phosphenes 33.6%, 16.4% spatial orientation, hand-eye coordination 13.3% | Occipital, occipito-temporal and occipito-parietal lobes |
| Sharma, Handa, Prakash, Nagpal K, Bhana, Gupta et al ²³ | Alexia without agraphia Right homonymous hemianopia | Left occipital lobe, corpus callosal splenium |
| Sohlberg, Griffiths, Fickas ²⁴ | Dyslexia | - |
| Galleta, Campanelli, Maul, Barrett ²⁵ | Dyslexia | Right Hemisphere |
| Beschin Cisari, Cubelli, Della Sala et al ²⁶ | 70% of participants omitted words from the left side of the text (Prose Reading Neglect). These differed only for the general gravity of the negligence. | Insula, putamen and right superior temporal gyrus. |

Legend: PCA - Posterior Cerebral Artery; CNS - Central Nervous System

Neuroanatomical correlations

Alterations in the visual field, especially hemianopsia, are among the most cited in the present review. It is defined by the partial or complete loss of vision in one of the visual field halves of one or both eyes. The homonymous hemianopsia is characterized by alteration of a hemifield by lesion in the left or right optic tract altering the nasal hemifield of one eye with the temporal hemifield of the other, both contralateral to the injured side. In a study that evaluated patients with sequelae of posterior stroke, all showed reductions in visual extension contralateral to the lesion and four patients presented bilateral reductions in visual space, despite unilateral lesions. Therefore, the visual range may be affected bilaterally by unilateral

lesions of the posterior circulation. Reductions in visual extension can also be confined to a hemifield and may be affected despite preserved visual processing speed¹⁷.

Alterations in the corpus callosum splenium, associated with the occipital lobe, were cited in two papers. In the study by Sharma et al.²³, a case of inability to read words, but with intact writing, and right homonymous hemianopsia, observed an infarction involving the left occipital lobe and corpus callosum splenium. Thus, cases of alexia without agraphia, although uncommon, should be considered in patients with reading difficulties and normal visual acuity. In the study by Gandhi et al.²¹, the case of a patient with alexia without agraphia due to left PCA infarction was described.

Interestingly, they observed a progressive Wallerian Degeneration (WD) in the corpus callosum splenium seen on MRI, with no references in the literature to the association with dyslexia. The authors inferred that WD had affected the critical splenic association fibers, resulting in this syndrome of unusual dissociation²¹.

In a sample of 128 subjects, the researchers observed visual field alterations in 52.3%, with reading impairments in 45.3%, phosphenes 33.6% (sensation of seeing light spots by mechanical, electrical or magnetic stimulation of the retina or visual cortex), 16.4% spatial orientation, hand-eye coordination 13.3%. Defects in the visual field, reading disorders and perception of phosphenes were mainly associated with calcarine sulcus lesions. Anomie and memory deficits were related to lesions of the inferior occipital gyrus, lingual gyrus and hippocampus, as well as lesions of the main tracts of the white matter²².

Inability/reading alteration, with intact writing, was described in four papers (33.3%). Alexia, also known as verbal blindness²⁰, was described by Joseph Jules Déjerine, who hypothesized that the disorders would be caused by subcortical lesions that functionally isolate the left angular gyrus (linguistic zone) of the visual cortex. The patient loses the ability to read but not to write or understand speech, and may be accompanied by homonymous hemianopsia on the right. The different patterns of injury may involve: a) the bundles of white matter that extend from the visual cortices to the left angular gyrus; b) lesions in the left splenium or visual cortex or; c) both the splenium and the lateral geniculate body. In these cases, the language zone is deprived of visual inputs, but remains intact. Therefore, symptoms in alexia may be caused by subcortical lesions that functionally isolate the angular gyrus (language-related area in the visual cortex). In this study, the picture originated in lesions in the left visual cortex and corpus callosum splenium due to left PCA occlusion and constrictions with right PCA dilatations - primary angiitis²⁰.

Linguistic characteristics

Based on linguistic performance, Sohlberg et al. identified that subjects after TBI exhibited, in relation to a control group, significant deficits in reading comprehension measures: a) paraphrase statements in a sentence verification task and b) communication units in a free recall task. The

results help elucidate the nature of reading comprehension in adults after TBI with mild to moderate cognitive deficits, emphasizing the need for a more in-depth assessment of reading comprehension strategies as a possible intervention option for these individuals²⁴.

Regarding therapeutic strategies, in a combined treatment for reading speed and spelling, three individuals with reading and spelling difficulties, after left ventricular occipito-temporal damage, demonstrated a faster and more accurate isolated word reading, with text reading rates. The accuracy of spelling also improved, particularly for untrained irregular words, demonstrating the generalization of the trained interactive spelling strategy. Combined use was efficient for reading and spelling performance¹⁹.

Moreover, when analyzing 67 subjects with dyslexia owing to neglect after stroke in the right hemisphere, researchers identified that the performance of reading texts (papers/menu) was significantly worse than reading of words and phrases. Thus, the assessment of neglect dyslexia should include text materials comparable to those read in everyday life. They also emphasized that increasing spatial extension of training materials in future researches may result in better functional generalization after right stroke, since spatial neglect is a neurocognitive disorder that affects perception, representation and/or motor planning²⁵.

Breschin et al. in order to analyze the relationship between reading in prose and other measures of negligence and its severity, they evaluated 30 subjects with stroke in the right hemisphere and defined symptoms of spatial neglect in daily life. Seventy percent of these participants omitted words at the beginning of the text (left end), showing negligence Prose Reading Neglect (PRN), which presented a lesion centered on the insula, putamen and superior temporal gyrus. Two disagreements arose between PRN and neglect in reading a single word, suggesting different cognitive requirements between the two tests: parallel processing in single-word reading versus serial analysis in reading the text. The neglected text pattern varied among participants who had PRN, including dissociations between the reading performance of single-column and two-column text. The reading of prose has proved to be a complex task, of singular abilities, that must be investigated to predict the effects of unilateral neglect²⁶.

The limitation of the present study is found in the number of selected papers, since the adopted criteria may have excluded important studies, especially when dealing with a subject with papers published in abundance in the international literature, but less explored in Brazil.

Conclusion

Considering the analysis of the selected studies, the initial perception regarding the lack of studies on acquired dyslexia was confirmed, implying a smaller resource for the clinical care of neurologically impaired patients with reading impairment.

Acquired dyslexia was present among the consequences of neurological damage due to stroke and TBI. Many papers have indicated occipital lobe lesion in individuals with acquired dyslexia, possibly justifying the difficulty of reading, because the damaged occipital lobe may have repercussions on visual difficulties, which interfere with the first reading process: visual recognition of the word.

In relation to the linguistic aspects, the papers indicate affection in both the right hemisphere and the left hemisphere, which possibly justifies alteration of the present language, from the perception stage, primordial for word recognition, to word processing.

Based on this research, it was possible to broaden the view on acquired dyslexia by linking linguistic and neurobiological approaches, including perceptual alterations. We suggest in future original research the insertion of neurophthalmological assessments in order to deepen the knowledge about these alterations, enabling new tools for speech-language assessment and, later, new clinical instruments for the rehabilitation process.

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