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The reading process: Implications and contributions of Neuroscience and Neuroeducation

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Abstract

This article immerses the reader in the descriptive analysis of the main characteristics of human behavior, functionality and brain activity during reading, thanks to the knowledge offered by neuroscience. It begins by publicizing the most relevant aspects of neuroscience, then dealing with its involvement in the educational field through neuroeducation and neurodidactics. Likewise, the reader learning process, access routes and cognitive processes involved are exposed in detail. It continues, with the exhibition of the reading areas, and ultimately, it explains how reading occurs. By way of conclusion, various implications of neuroscience in the educational treatment of the teaching and learning of reading are presented. In short, it reflects the way in which neuroscience reveals the possibilities of the human brain in reading tasks, and the ability of this science to work together with educational sciences and thus improve various learning processes.

Key Words: neuroscience; neuroeducation; brain; learning; reading

1. Introduction

The subject that is approached starts from neuroscience, this being the backbone from which one of the essential pillars in the formation of a person, education, will be deepened. Therefore, later, we take care of giving an updated vision to this topic, where both neuroscience and teaching are linked, thus emerging, a new term, with which we can understand the process of learning to read.

That said, the main objective that this article aims to achieve is to analyze and comprehensively describe the essential characteristics of the functioning, behavior and activity of the human brain during reading, through the knowledge provided by neuroscience. In the same way, it is important that we also attend to the achievement of other more specific objectives. Consequently, in the first place, we must know the most relevant aspects of neuroscience as a scientific discipline. Second, understand the implication of neuroscience in education. Third, publicize the reader learning process and the elements that make it up. Fourth, determine the operation and organization of the areas specialized in reading. Lastly, visualize the implications of neuroscience in the didactic treatment of reading.

On the other hand, in terms of the methodology used, it is that of a theoretical review on the contributions of neuroscience in the process of learning to read. By virtue of this, an extensive search and compilation has been carried out on the subject under study. In relation to the bibliographic search process that we have undertaken, it should be noted that we selected some reliable databases and sources of data, these being: "Academic Google", "Wos (Web of Science)", "Scopus", "Redalyc", "ScienceDirect "," Scielo "," Eric "and" Dialnet ". In them, keywords were introduced in order to obtain a more accurate and valid information. Some of these were: neuroscience, neuroeducation, reading and neuroscience or brain and reading. In addition, two types of searches have been differentiated, one focused on the contextualization of the work and another for the review of works already prepared.

Subsequently, due to the large amount of information found, inclusion criteria were applied for the choice of articles to be reviewed, among which the following stand out: priority of secure academic sources, relatively current information, of a certain educational nature and English, Spanish or French speaking.

2. Theoretical Framework

2.1. Concept of Neuroscience and Neuroeducation

First of all, we approach the term neuroscience from the perspective of different authors. The definitions provided are relatively current and provide relevant information about this terminology. It should be noted that many definitions have been proposed for this term, and that today there is no single definition, although if it is true, that several are used to give meaning to the term.

respect. On the one hand, Blakemore and Frith (2011) argue that the term neuroscience is a type of umbrella that houses different knowledge, and in which disciplines such as physics, medicine, biology or psychology, among others, come together, with the goal of knowing both the function, development and structure of the brain, as well as the functioning of neurons and the pathology of the nervous system, in order to know the biological bases that support human behavior. In this way, it is possible to establish a correlation between the cognitive functions and the behaviors of the human being, thus developing a new style of understanding the mind. On the other hand, Mora and Sanguinetti (2004) are committed to understanding neuroscience as a discipline in charge of studying the structure, function, development, pathology and pharmacology of the nervous system (p. 75). As for the concept of neuroeducation, it is closely related to that of neuroscience. Likewise, despite this connection, not everything related to neuroscience has applicability to the educational field. For this reason, it is the teacher who has to distinguish between what is significant and realistic to apply in teaching practice and what are, merely, opinions without any basis. Focusing now on the concept of neuroeducation, this is considered a discipline still under construction, which is responsible for optimizing the learning and teaching process, based on brain development. In this way, neuroeducation is able to take advantage of different brain images in order to improve teaching techniques and adapt them to each student's brain. Likewise, this discipline aims to use knowledge based on neural and / or brain images, and transfer them to educational agents, in order to demonstrate the way in which the student's brain interacts with the environment in which it is carried out the teaching and learning process (Hernández and De Barros, 2015).

In summary, we must understand neuroscience and with it, neuroeducation as a more extensive way of knowing about everything that happens in the brain. That is, how it learns, how it processes, preserves, records and evokes information, so that based on brain knowledge, a wide variety of optimizations of experiences and learning proposals can be extrapolated to the classroom.

2.2. Goals of neuroscience in Education

Next, we proceed to explain the objectives that neuroscience aims to achieve in the educational field. This science is characterized and aims to visualize the functions of the brain, having this, a high benefit to understand a wide range of processes, tasks, disorders or difficulties that students have. On the one hand, Mendoza, Murillo and Maldonado (2019), understand that to successfully face the contributions of neuroscience in education, a type of teaching behavior is needed that is above all, emotionally intelligent, and that is capable of searching of other didactic possibilities that precede neuroscience, considering it as a scientific and research instrument. On the other hand, the undeniable impact of neuroscience on the learning process continues to be confirmed. Hence, carrying out teaching and methodological strategies in the classroom, in relation to scientific results from neuroscientific studies, has a positive impact on the effects of real meaningful learning, which optimizes the teaching and learning process itself. Given that neuroscience has a particular interest in how the activities of the brain are related to the behavior and learning of the person, it is essential that a dialogue is necessarily undertaken between neuroscientists and teachers, with the purpose of bringing to light many other benefits that hides the human brain within the repertoire of cognitive responses that occur in the teaching and learning of the student (Puebla and Paz, 2011).

In short, we can affirm that each brain is unrepeatable and unique, and for this reason, neurosciences show the educational world which is the path that today's pedagogy must follow.

2.3. Neurodidactics

Our purpose here is to reflect some ideas that manifest the way of doing didactics under the knowledge of neuroscience. This is, what we previously called neuroeducation, will be treated from the possibilities that some authors of this science throw to do didactics, thus emerging what is known as neurodidactics or didactics of neuroscience.

Following this line, Hruby and Goswami (2011), consider that from the point of view of neuroscience, learning is an interesting factor during the school stage, because at this time, the brain develops multiple connections that will later become in knowledge networks, giving rise to memory. Therefore, learning new knowledge allows the production of neurons and detrital bonds, creating a larger and more complex network of neurons. In this case, learning seen from neuroscience, supposes, above all, changes in the connectivity of neurons, alteration of the release of neurotransmitters, as well as the strengthening or elimination of neurons due to experience and learning.

In short, Paniagua (2013) concludes that neurodidactics is a variant of pedagogy based on neuroscience, based on the application of knowledge about the functioning of the brain and how neural processes intervene in learning to help it be more optimal. Its purpose is to support existing methodological and didactic strategies to promote greater brain development in terms that educators can understand and interpret, since without the latter, its implementation would be impossible.

3. The process of Learning to Read

3.1. Cognitive Processes Involved in Reading

Next, we aim to expose those cognitive processes that come into play during reading activity. These skills and processes are numerous, and the following stand out: perceptual-visual processes, phonological processes, skills phonological awareness, phonological working memory skills, lexicon entry skills, automation processes, morphological processes and finally, prosodic processes (Defior, Serrano & Gutiérrez, 2015). Regarding what we are dealing with, it should be said that reading is a skill that is acquired through great effort and therefore, a long time dedicated to its practice. Reading is mainly a phonological activity, but it is also a task that works on visual perception.

Similarly, to understand this ability, it is important to expose the processes and skills that intervene in it. In the first place, in terms of perceptual and visual processes, we emphasize that reading always starts from a visual input. Furthermore, letter recognition is key to predict reading learning in alphabetic systems (Caravolas et al., 2012). Secondly, with regard to phonological processes, it is worth highlighting the relationship between the acquisition of reading and writing, and three areas of phonological processing, being the following: verbal short-term memory, phonological awareness and the phonological lexicon. The first ability is implicit, the second is explicit, and the last is implicit (Defior and Serrano, 2011). Third, the skills related to phonological awareness, refer to those whose purpose is to indicate the knowledge that each person has explicit about the sounds of their language. In this sense, it consists of the ability to intentionally segment, identify or merge the syllables and phonemes of a word. Within this ability, there are different levels, including lexical awareness, rhyme, syllabic, intrasyllabic and phonemic (Defior, Justicia and Martos, 1998).

Fourth, phonological working memory skills point to the ability to encode a miniscule amount of verbal information, to later accumulate and maintain it temporarily using a system of sound representation, while new information is being processed (Gutiérrez, Raya & Palma, 2009). Fifth, lexicon entry skills rely on the automatic retrieval of familiar word phonologies, without explicit reflection time required. Sixth, automation processes involve the automation, properly speaking, of the grapheme-phoneme conversion rules. Penultimate and seventh, phonological processes refer to the increase in knowledge of graphemes that occurs as reading progresses, recognizing graphemes as abstract units (Nunes and Bryant, 2006). Finally, the prosodic processes show their interest in the development and acquisition of reading and writing, also known as suprasegmental phonology (Peterson and Pennington, 2012).

3.2. Ways of Access to Reading

This section provides a detailed description of the two access paths to reading. It is of interest to point out that in reading, visual signals behave as auditory signals in alphabetic and syllabic systems, due to the fact that ocular information transmits phonological and linguistic information. Therefore, alphabetic schemes constitute the phonemes of a language, giving rise to the possibility of representing all possible words and messages as a set of symbols, being also necessary to know the sound correspondences of each symbol of the alphabet in order to produce words. Thus, in order to read, the reader must identify and differentiate between the various visual symbols, isolated and in a group, must give each symbol a sound, and mostly, recognize each word as a significant spelling configuration, giving it a pronunciation. (Defior, Serrano and Gutiérrez, 2015). In addition to the above, Dehaene (2011) argues that to know how to read it is enough to recognize the sound that each letter has; In reading, most of the words in a language, in our case, Spanish, can be read by converting graphemes into phonemes. Indeed, the degree of difficulty in learning to read is different depending on the language.

Thus, the double path model proposes the use of a direct path, also called visual or lexical, and an indirect path, also known as phonological or sublexic. As for the visual or lexical route, according to Cuetos (2008), it is used when the visual lexicon that each subject has is entered directly, being formed by the orthographic representations of the words that the individual has added. during your time of reading experience. Access to this type of lexical “deposit” does not necessarily mean being able to obtain the specific meaning of the word, but quite the opposite, that is, connecting or linking with the semantic system. That is, the reader can recognize a word without really knowing its meaning. In this way, this repository organizes the concepts into various categories. If the reading takes place aloud, the phonological lexicon, formed by their respective phonological representations, will have to be activated, proceeding to the articulation of the word to be read. Consequently, the route described is made up of three elements: the visual lexicon, the phonological lexicon, and the semantic system. However, although.

These elements differ from each other, they interact in parallel in order to quickly access the word as if it were a whole.

On the other hand, and looking back to Cuetos (2008), the phonological or indirect route is one that allows the reader to read the words through the gradual conversion of the letters into sounds, which is known as the grapheme-conversion process. phoneme, which we have already talked about previously. This process is made up of different sub-processes. The first, the analysis of graphemes, in which the graphemes are separated, the second, the assignment of phonemes, whose function is to identify the sounds corresponding to each grapheme; and the third, the coupling of phonemes, which allows articulation to occur.

In relation to the visual path and its implication with brain functions, it is interesting to say that in order to interpret written words, a region of the brain, more specifically, that of the visual cortex, called the area of the visual form of the words, exerts the function of storage of the visual knowledge that we have about the letters and their multiple combinations. The response in this area increases as learning to read improves, as neurons begin to specialize with the most frequent letters and words in our environment and vocabulary.

It is a synthesis, as Cohen and Dehaene (2004) point out, learning to read is to take advantage of a part of the visual cortex, so that the neurons that are there, give meaning to the shapes of the letters and therefore, to their combinations.

4. Neuroscience of Reading

4.1. Brain areas Involved in Reading

It is necessary to specify how the brain is organized during reading, with special emphasis on identifying and locating the neural systems used to read. Reading requires many areas of the brain to work together through a complex network of neurons. However, it must be clear that there is no region of the brain that is specifically dedicated to reading, but that the "reading system" is previously built on a series of brain structures. In other words, other systems of the brain operate in a joint way with the purpose of being able to create a new functional system and form a function, this being reading (López-Escribano, 2009).

The development of reading is conditioned by the coordination of certain components present in the recognition of words, orthographic, phonological and semantic. Thanks to the advances made in neuroimaging, a good identification of the reader circuit is facilitated. According to Perfetti and Bolger (2004), they state that this reading circuit mainly includes three brain areas, located in the left hemisphere of the brain, in which we find, (a) the ventral area (occipito-temporal), (b) the area dorsal, this being a temporal-parietal area, corresponding basically to the well-known Wernicke area, and (c) the left frontal area, which includes Broca's area, the inferior frontal gyrus and the insular cortex. Similarly, in the ventral area the visual processes and orthographic, in the dorsal area or Wernicke's area, the decoding and phonological processes take place, and in the frontal area or Broca's area, the articulatory-phonological and semantic processes take place.

Hruby and Goswami (2011) suggest, on the one hand, that syntactic processes are associated with an activity in the left frontal gyrus or in Broca's area. On the other hand, semantic processes are located in one area or another depending on whether or not they are found at the word level (posterior superior temporal and temporal parietal areas; for example, Wernicke's area and the supramarginal gyrus or temporal sulcus) . At the sentence level, it is located in the left frontal area, close to Broca's area, and at the text level it is located in the frontal and parietal lobe area (p. 164).

4.2. Reading in the Brain

A posteriori, we set out to describe the path that reading follows in the brain. On the one hand, we emphasize that reading requires the interaction of various parts of the brain, which, when interrelated, form a brain circuit. That said, it would be incorrect to say that this written language brain circuit sits solely in the left hemisphere. In relation to which, it should be emphasized that for a vast majority of the population, around 87%, reading is predominantly in the left hemisphere; however, for a small percentage, around 8%, it is located in the right hemisphere; for the rest, 5%, it is distributed both in one hemisphere and in the other, without there being a clear definition (Narbona and Fernández, 1996). On the other hand, learning to read produces changes in cognitive processing. That is, once a child learns to read, the brain areas that were previously used to process different stimuli, become part of a new specialized area, the area of the visual form of words, which we will talk about later. . Therefore, this reuse is what is known as neuronal recycling (Muñoz, 2016).

In general, we already know that reading is not the same in all individuals. In addition to being located in one hemisphere or another, the same happens depending on the language, and it is that the brain circuits that are activated differ depending on this last factor. Thus, in some languages there is a sound-letter relationship, as in our case, Spanish, where there is greater stimulation in Wernicke's area and in the angular gyrus, thus favoring the creation of new words. By virtue of this, Gabrieli, Christodoulou, O'Loughlin and Eddy (2010) indicate that it is currently known with precision that the left posterior region of the brain is responsible for selectively responding to words and letters. Similarly, for Dehaene (2009c), reading learning consists of the connection of two sets of brain areas that are present from an early age: the object recognition system (visual) and the language circuit.

So, reading is divided into a series of information processing phases. In the initial phase, the first great activator of the neural circuit of reading is the visual one, based on the reaction that occurs in the occipital region through the visual input of the written word. Without effort.

Some, the human brain has the ability to visually recognize written words thanks to a specific brain region for it. Only the center of the retina, known as the fovea (it covers approximately 15º of the visual field), is the most useful section of the retina for reading (Sere, Marendaz & Hérault, 2000). Then, once the word has entered the retina, it is separated into multiple portions by the neurons that exist in the retina. Portions that are previously coupled to later decode the graphemes that form it before recognizing the word. Consequently, our visual system is capable of reducing the word that we visualize to the skeleton that makes it up, ignoring its size or font, thus generating a standard code per word. This codification raises a hierarchy of the word, going from seeing it as a whole, to the production of a decomposition of it, into morphemes, syllables and graphemes.

Thanks to neuroimaging, we know that in the region that is activated due to the input of a visual stimulus, the occipito-temporal region, the presence of an area of the left visual system of the brain is confirmed, which produces an alteration in the reading of selectively. This area has an essential and specific role in reading, and is called the brain's “box of letters”, this being where the second phase of reading begins in our brain. This area is located in the same cortical zone in all readers and responds automatically to written words. For one thing, the posterior regions of the left hemisphere do not.

They have the selective function in reading. On the other hand, the regions (occipitals) are involved in the first periods of visual analysis, without being specific in reading, but rather help the visual recognition of a shape, object or color. Thus, the temporo-occipital area of the so-called "letter box" discriminates the visual form of words. A posteriori, it distributes this visual information to different regions of the left hemisphere, where both the meaning of the letter strings and their sound are encoded, through one of the two language routes, as well as their articulation (Wolf, 2008).

Indeed, this area of the visual form of the words or letter box of the brain plays a crucial role, since it is in charge of connecting the visual input with the language networks, thus acting as an area of association. In attention to the two brain networks of language (the phonological route and the lexical route), they come into play in a parallel way, however, they follow an uneven path in our brain. Regarding the phonological or indirect route, it is directed towards the temporal lobe, in which the corresponding conversion of graphemes to phonemes takes place. Phonemes are analyzed in the supramarginal turn to later generate their meaning, followed by the composition of the word as a whole, to articulate it in the last place. It should be said that this route is used to read new words and therefore, for learner readers. As for the lexical or direct route, it is used for words that we do not decompose morphologically but that we use recurrently. Thus, this route leads the visual signal to the supra-temporal gyrus to provide the graphemes with meaning, without the need to resort to a phonological representation. On the other hand, semantic relationships put into operation a new region, the left inner prefrontal cortex, which is generally linked to creative thinking (Hasson, Harel, Levy & Malach, 2003, p. 32).

In conclusion, in reading there is no dominant hemisphere, reading involves neural recycling and the involvement of a broad neural network. For Dehaene (2009b), reading is, then, developing a connection between visual areas and language areas, these and all connections being bidirectional.

4.3. The Didactic Treatment of Reading from Neuroscience

In this last section, we pay particular attention to the various implications that neuroscience has carried out in the classroom for the teaching of reading. By virtue of this, Berninger and Richards (2002) describe a series of educational practices based on neuroscience, which must be carried out progressively as learning to read progresses. First of all, we talk about early stimulation programs. It would be appropriate to apply these programs around 18 months, at which time dendrites are increasing in the left hemisphere and expressive language begins to resurface. Well, during this time it is essential to talk with infants and read stories to them, even though their expressive capacity is low. In this way, it is essential to stimulate the language, since the posterior areas destined to the understanding of the language advance more quickly than the frontal areas, focused on the production of the same. In addition, these authors point out that in teaching letters and words, it is It is important to create multiple connections between them, because the various forms of words are found in different areas of the brain.

Beginning readers maintain the visual form of words in the short term in phonological memory (Moats, 2004). Consequently, the teaching of self-regulation techniques in reading will allow a greater maturation of the frontal lobes. Therefore, the regulation of an adult's hand can provide the reader with explicit clues of how to read, through guided instructions or scaffolding. On the other hand, the repetitive reading of texts causes the automation of word recognition, and this process is transferred to the circuits that involve the cerebellum (Santiuste and López-Escribano, 2005).

Regarding the methods of learning and teaching reading, two have long reigned, the phonic and the global. There are controversies between the benefits and drawbacks of one or the other. On the one hand, the phonic method aims to intentionally and systematically teach the grapheme-phoneme correspondence, allowing the child to read any word. On the other hand, the global method proposes to teach the reader the recognition of the direct associations that exist between written words and their respective meanings, without carrying out a phonological decoding. This last method, gives rise to very limited results, however, many educators defend it. Lebrero, Fernández-Pérez and García-García (2015) consider that the immediacy of reading approaches an illusion caused by the automaticity of the stages that comprise it, without a conscious perception. What is true is that understanding and learning the grapheme-phoneme conversion code is important in learning and teaching to read. In this way, our brain recognizes words by separating them into letters and graphemes, processing in parallel in the area of the brain's letter box, located in the left temporo-occipital cortex. Thus, Dehaene (2011) supports that the phonic method is the most optimal when teaching reading, because the systematic teaching of the grapheme-phoneme correspondence offers better performance, having better results in the comprehension of texts thanks to the correct and essential decoding. Thus, the more the grapheme-to-phoneme conversions are automated, the more the reader concentrates on the meaning of what he is reading.

Neuroimaging reveals that in the brain of dyslexic children there is an increase in the activation of the posterior regions of the left hemisphere. For this reason, educational intervention programs based on the phonological deficit model have been proposed, the main purpose of which is to stimulate the phonological awareness of students with this type of disorder. In this way, Simos et al. (2002) state that once this intervention with phonological programs has been successfully completed, significant variations occur in the brain activation profiles in students with dyslexia, producing improvements in reading decoding and showing important changes in the activation of the temporo-occipital areas of the left hemisphere, now yes, with an activation more typical of non-dyslexic students.

By way of conclusion, it should be noted that brain studies provided by neuroscience to education show that dyslexic people, especially, present difficulties in auditory, phonological and visual processing tasks. For Consequently, they present less activity in the left hemisphere of the temporo-occipital and parietal lobe during the previously mentioned tasks (López-Escribano, 2007).

5. Conclusion

First, neuroscience turns out to be an emerging and collaborative science, which has a primary interest in the study of the anatomy and behavior of the human brain. Therefore, it facilitates the understanding of how the brain has the ability to produce the individualization of the actions of a subject, and thus, apply part of it to explain the way of acting of boys and girls during the school stage.

Second, neuroeducation can be understood as an ideal opportunity to take advantage of the knowledge provided by neuroscience in order to optimize the teaching and learning process, based on the brain function of students.

Third, learning to read is an essential and basic skill for the development of any person in a literate society. However, its acquisition is complex and diverse depending on the needs of the apprentice. In addition, their learning, which goes through various stages, requires progression, revision and caution, since reading well does not only depend on speed, but on adequate understanding.

Lastly, the contributions of neuroscience in the educational treatment of reading are beneficial when it comes to serving students according to their individual characteristics and needs during learning to read. In addition, it allows educators to know which educational programs are the most appropriate to apply in dyslexic students, depending on those brain areas in which this reading deficit falls, and in this way, alleviate the difficulties that these readers present.

In short, neuroscience and neuroimaging studies reveal the multiple possibilities of the human brain, holistic in function and in tasks as difficult as reading, where neural networks are capable of encompassing various structures, areas and regions at the same time. cerebral. Therefore, in the near future, the harmony between neuroscience and educational sciences would be enriching to favor the development and approach of brain behavior in learning tasks.

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