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Contributions of cognitive neuroscience to distance education in higher education

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Abstract: This study aims to understand how Cognitive Neuroscience (NC) can contribute to improving the teaching and learning process in Distance Education (EaD) in Higher Education (ES). After a literature review in different scientific databases,

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we found that there is a lack of research that addresses the intersection between NC and EaD. Therefore, we highlight the need for a deeper understanding at the higher education level.

Keywords: Cognitive Neuroscience; Distance Education; Higher Education.

Contribuições da Neurociência Cognitiva para a Educação a Distância no Ensino Superior

Resumo: O trabalho tem como objetivo compreender como a Neurociência Cognitiva (NC) pode contribuir para melhorar o processo de ensino e aprendizagem na Educação a Distância (EaD) no Ensino Superior (ES). Após uma pesquisa bibliográfica, em diferentes bases de dados científicos, constatamos que há uma escassez de pesquisas que abordem a interseção entre NC e EaD. Destacamos, portanto, a necessidade de uma compreensão mais aprofundada para o nível superior.

Palavras-chave: Neurociência Cognitiva; Educação a Distância; Ensino Superior

Aportes de la Neurociencia Cognitiva a la Educación a Distancia en la Educación Superior

Resumen: El objetivo de este trabajo es comprender cómo la Neurociencia Cognitiva (NC) puede contribuir a mejorar el proceso de enseñanza y aprendizaje en la Educación a Distancia (EaD), en la Educación Superior (ES). Luego de una investigación bibliográfica, en diferentes bases de datos científicas, encontramos que faltan investigaciones que aborden la intersección entre NC y EaD. Destacamos, por tanto, la necesidad de una comprensión más profunda para el nivel superior.

Palabras clave: Neurociencia Cognitiva; Educación a distancia; Enseñanza Superior

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1 INTRODUCTION

The functioning of the brain contributes to all forms of education, including Distance Education (EaD), to improve educational methods for the teaching and learning process. In order to better understand this functioning, this work is based on the contributions of Cognitive Neuroscience (NC), especially Executive Functions.

NC is a field of science that has recently emerged from cognitive psychology, which studies higher mental functions, and neuroscience, which studies the brain structures that support these functions. In this way, it has made it possible to study the brain and the mind and to make progress in various fields, such as education.

The methodology of this research has been carried out through a literature review and searches in databases such as the Coordination of Superior Level Staff Improvement (CAPES), ResearchGate, Google Scholar, and Semantic Scholar, thus substantiating the possible relationships and inferences underlying the purpose of this study. The main objectives are to understand how NC can contribute to improving the teaching and learning process in Distance Education, in Higher Education (ES); to propose a bibliographic search in scientific databases that present theses, dissertations, or articles on Cognitive Neuroscience and EaD; and to understand the contributions of Cognitive Neuroscience to education in Higher Education.

Thus, in addition to the studies found in the various databases, scholars such as Diamond (2013), Cosenza and Guerra (2011), the Scientific Committee of the Science for Childhood Center (2016), and Relvas (2009) were consulted as bibliographies to broaden the data found.

2 DEVELOPMENT: theoretical basis, methodology and data analysis

2.1 Theoretical foundation

2.1.1 Concepts in Cognitive Neuroscience

Studies of the brain began in ancient Greece, but the term neuroscience was not adopted until 1970 when the use of technology allowed neuroscientists to make significant discoveries with brain mapping (BRASIL, 2021). Neuroscience can take six different approaches, as noted by Grossi *et al*. (2014):

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- Molecular neuroscience: studies the chemistry and physics involved in neural function. It studies the various molecules of functional importance in the Nervous System (SN);
- Cellular neuroscience: considers the differences between the types of cells in the SN and how each works;
- Systemic neuroscience: studies the regions of the SN, processes such as perception, discernment, attention and thought;
- Behavioral neuroscience: studies the interaction between the systems that influence behavior, explains the mental capacities that produce behaviors such as sleep, emotions, visual sensations, among others;
- Cognitive neuroscience: studies more complex mental abilities such as learning, language, memory, planning;
- Clinical neuroscience: studies the pathologies of the SN.

Among these, Cognitive Neuroscience is considered a multidisciplinary field dedicated to understanding how the brain processes information and how it relates to cognition and human behavior. Grossi and Borja (2016) explain that because it is considered multidisciplinary and dedicated to studying the functioning of the SN, it collaborates with different fields of knowledge such as biology, engineering, anthropology, medicine, and education. In this context, Relvas (2009) explains that Neuroscience studies the SN on a scientific basis, relating it to education and revealing how important the brain is in the learning process.

Thus, knowing some concepts of Neuroscience allows us to broaden our view of how it can contribute to educational processes. The brain is the most important part of the nervous system, because through its functioning we become aware of the information coming through the sense organs, allowing us to process information, compare it with experiences and expectations, as well as the body's voluntary and involuntary responses. This process is carried out by nerve circuits, made up of billions of cells called neurons, which process and transmit information through nerve impulses (COSENZA; GUERRA, 2011).

The aforementioned authors also explain that for information to be transmitted from one cell to another, it depends on the presence of a structure that is almost always present at the end of the neural extension, called an axon. These areas that promote the passage of information between cells are called synapses, and communication between them is carried out through the release of a chemical substance called a neurotransmit.

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At the synapses, neurotransmitters are released and act on the membrane of the other cell, stimulating it to fire nerve impulses or even inhibiting new nerve impulses, as many neurotransmitters are considered inhibitory. In this way, synapses regulate the passage of information through the nervous system and thus play an important role in the learning process (COSENZA; GUERRA, 2011).

Cosenza and Guerra (2011) also point out that the axons present in the nervous system have a myelin wrapping and explain that:

> The axon is the extension through which the neuron conducts the information that will eventually be transmitted to other cells, and the speed of this conduction is an important factor. The myelin sheath is made up of auxiliary cells that wrap around the nerve fiber, or axon. Myelinated fibers can be more efficient, as axons with this sheath conduct information up to 100 times faster than non-myelinated fibers (COSENZA; GUERRA, 2011, p. 15, translated by us).

In this regard, the authors explain that when the human brain is sliced and examined, the areas with myelinated fibers are visible as white matter, while the areas with a predominance of neuron bodies are gray matter. They go on to say that the outer part of the brain consists of a layer of gray matter called the cerebral cortex, which is responsible for functions such as language, action planning, memory, and critical thinking.

Because of the above, it should be emphasized that neuroscience, by explaining how the brain works and how neural connections occur in the cognitive process, also explains the factors that cause learning disabilities, difficulties, and neurocognitive disorders, which have a significant impact on education (BRASIL, 2021).

2.1.2 Cognitive Neuroscience and Education

The learning process occurs in the physical, neurological, cognitive, and behavioral structures throughout a person's life. In this sense, developmentalists have sought to understand how and why Neuroscience contributes to the learning process and aim to elucidate the approach of Neuroscience in learning as an educational tool to solve learning problems in the cognitive development of students. This theory shows us the importance of the brain as the main learning organ involved in the entire development of the individual.

Based on the studies of Relvas (2009), Neuroscience in

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Education aims to study the development and functioning of the nervous system and to assist educational professionals in developing more appropriate pedagogical methodologies in the development of education and in the process of learning difficulties.

The studies by Grossi, Lopes and Couto (2014) are based on the contributions of renowned authors who have used neuroscience to understand psycho-pedagogical processes, among them: the Swiss Jean Piaget (1896-1980) with his stages of development (sensorimotor, pre-operative, concrete operative and formal operative) and the Belarusian Lev Semenovich Vygotsky (1896-1934) with the zone of proximal development, which defines the distance between the actual development and the potential development of learning.

Therefore, it is essential to understand how the brain works in order to better use it and thus rethink student learning. According to Bartoszeck (2003), Neuroscience offers great potential for guiding learning in the classroom and points to some of its principles that can be applied, as shown in Chart 1:

Chart 1. Principles of Neuroscience with potential application in the classroom

Principles of Neuroscience	Classroom environment
1. Learning & memory and emotions are interconnected when activated by the learning process	Learning being a social activity, students need opportunities to discuss topics. A calm environment encourages students to express their feelings and ideas.
2. The brain gradually changes physiologically and structurally as a result of experience.	Practical lessons/physical exercises with the active involvement of students make associations between previous experiences and current understanding.
3. The brain shows optimal periods (sensitive periods) for certain types of learning, which do not end even in adulthood.	Adjustment of expectations and performance standards to the specific age characteristics of students, use of integrative thematic units.
4. The brain shows neuronal plasticity (synaptogenesis), but greater synaptic density does not predict greater generalized ability to learn.	Students need to feel in control of the activities and themes that are relevant to their lives. Pre-selected activities with a choice of tasks increases students' responsibility for their learning..
5. Numerous areas of the cerebral cortex are simultaneously activated in the course of a new learning experience.	Simultaneously activated in the course of a new learning experience. Situations that reflect the context of real life, so that new information is anchored in previous understanding.
6. The brain was evolutionarily designed to perceive and generate patterns when testing hypotheses.	Promoting situations in which attempts and approximations are accepted when generating hypotheses and presenting evidence. Use of case resolution and simulations.
7. Due to its primitive heritage, the brain responds to pictures, images and symbols.	Provide opportunities for students to express knowledge through visual arts, music and role-playing.

Source: Bartoszeck (2003), modified from Rushton and Larkin (2001). Chart translation adapted from original in Portuguese..

Based on the information in Chart 1, we highlight the importance of these principles for

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professionals working in the field of education, as neuroscience can contribute to the quality of teaching and student learning in terms of: more hands-on lessons; a calm classroom environment so that students feel safe to express their opinions; student performance according to their age group and activities that include topics relevant to their daily practice; seeking interdisciplinarity between fields of knowledge such as visual arts, music, and drama.

In this context, teachers need to have a background in neuroscience so that they can understand how learning takes place and feel more confident in developing more varied and challenging activities such as cognitive exercises, as well as adapting the curriculum, pedagogical didactics, and professional qualifications.

Thus, as another resource to be used in classroom learning, it favors the teacher's ways of teaching and, as a consequence, the student's learning. Therefore, the study and application of neuroscience is essential, because the teaching and learning process will take place gradually, based on the environment in which the student lives and an understanding of the functions of the brain (BARTOSZECK, 2003).

Therefore, in the next section, we will look at the contributions that Neuroscience has made through executive functions.

2.1.3 Executive functions

Undeniably, Neuroscience has made extremely important contributions to the field of education, making it possible to understand the teaching and learning process throughout life by understanding brain functions (COSENZA; GUERRA, 2011). At the same time, and more specifically after the studies on Phineas Gage and the impact of his accident on his social life, the understanding of the functioning of the brain, especially the part of the prefrontal cortex, has taken on greater proportions, as it is part of all the neural processing of information received by the brain and, consequently, of its actions (DAMÁSIO, 2012).

Phineas Gage, who was 25 years old in 1818, was a construction foreman working for the Rutland & Burlington Railroad, laying track for the Vermont Railroad. The rugged, rocky terrain forced workers to use explosives to level and straighten the ground. Phineas Gage, with his athletic build and height of 5'7", was the coordinator of this task and was considered the most efficient worker by his superiors due to his dexterity, precision, and efficiency (DAMÁSIO, 2012).

Phineas Gage was also considered to be

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an affable person, respectful of the norms of society, persistent, intelligent, with a balanced mind. However, a mistake in handling the explosives caused an accident that would change his life: in a fraction of a second, a six-kilogram iron rod "pierced the base of his skull, passed through the front of his brain and exited at high speed through the top of his head" (DAMÁSIO, 2012, p. 29, translated by us). Phineas Gage would not die, but from then on his personality would change completely, losing inhibition in his speech and actions, often becoming obscene, showing little respect for his acquaintances, impatient with social restrictions, among other situations. The case of Phineas Gage completely changed the panorama of brain studies and is still a reference point for neuroscience and its various fields of study that are still developing today (DAMÁSIO, 2012).

From the perspective of neuroscience, other aspects related to the brain's functionality have also gained notable prominence: these are the so-called executive functions. Based on this brief introduction, it is important to understand them and how they affect the teaching and learning process.

The Executive Functions (FEs) are directly involved in all cognitive processes in an integrated manner and are necessary for impulse control, concentration, and decision-making (ROCHA, 2018). The proper functioning of the EFs makes it possible to live autonomously and within an adequate social panorama.

According to the Scientific Committee of the Science for Childhood Center (2016),

> Executive functions are a set of skills that enable mindful thinking, that is, deliberate, goal-oriented thinking. Good executive functioning allows the individual to think before acting, to mentally work through different ideas, to solve unexpected challenges, to think from different perspectives, to reconsider opinions, and to avoid distractions. Thus, these skills are fundamental for making decisions, living, and thinking independently (COMITÊ CIENTÍFICO DO NÚCLEO CIÊNCIA PELA INFÂNCIA, 2016, p. 5, translated by us).

In this way, it is possible to understand that the development of FEs is important for them to act fully in everyday life, allowing them to act and interact with society coherently and following the social rules historically defined by the community to which they belong. It should be noted that the development of EFs is also related to mental and physical health, school success and full psychological, cognitive and social development (DIAMOND, 2013).

Although there is no unanimous classification of FEs (MALLOY-DINIZ, 2020), we will follow the model established by Diamond (2013), the main EFs are: Operational Memory or Working Memory, Inhibitory Control, and Cognitive Flexibility.

Operational Memory (MO) or Working

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Memory (MT) is a component of EFs that allows us to store and work with information for a short period. It is essential because it is used in everything that unfolds over time and requires the mind to store certain information to relate it at an opportune moment (DIAMOND, 2013).

MO is related to other everyday functions, such as relating previously recorded information in order to follow a certain path or route, or even to define which would be the fastest to follow.

> This allows different facts or events to be stored and then manipulated. In this way, this skill allows different readiness strategies to be stored over a period to be used in response to different stimuli and circumstances (for example, saying thank you after a kindness) (SCIENTIFIC COMMITTEE OF THE SCIENCE FOR CHILDREN CENTER, 2016, p. 5, translated by us).

Cosenza and Guerra (2011) point out that MO, through attention facilitated by inhibitory control, a component we will discuss below, allows the brain to store certain information and also correlate it with other similar information, thus consolidating it as learning. It's important to note that for information to become significant, it must pass through the filter of attention, through what the authors define as repetition, and then be associated with other information or elements through elaboration, and finally be consolidated, in other words, transformed into learning.

In this way, MO allows different pieces of information to be connected and related. The same happens with different events at different times, making it possible to mentally reorganize these elements. Because of the way it works, it makes it possible to plan and organize actions (SCIENTIFIC COMMITTEE OF THE SCIENCE FOR CHILDREN CENTER, 2016).

Inhibitory Control, as its name suggests, refers to the component of FEs associated with the inhibition of inappropriate and/or impulsive attitudes and behaviors that are out of sync with the social environment. In addition to controlling impulses and behaviors, inhibitory control is responsible for attention, thinking, and emotions. According to the Scientific Committee of The Science for Children Center (2016), three aspects of Inhibitory Control are relevant. The first is the inhibitory control of attention, which is related to focusing and avoiding visual and/or auditory stimuli that could be distracting.

Cognitive inhibition, on the other hand, is related to the resistance and control of unwanted thoughts and memories that can eventually cause distraction, "[...] it makes it possible to remain focused on the desired information, even in the presence of some involuntary thought" (SCIENTIFIC COMMITTEE OF THE SCIENCE FOR CHILDREN CENTER, 2016, p. 6, translated by us).

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Next, we have self-control, which is nothing more than controlling oneself even under intense emotions and/or impulses. Self-control allows you to avoid inappropriate behavior, such as outbursts of aggression, whether physical or verbal, as well as control to achieve specific goals, even with distractions along the way.

In this way, self-control allows a degree of autonomy in conscious decision-making, avoiding unwanted emotional outbursts.

> Having self-control means having the ability to act in a way that is different from what is intimately desired, such as having the discipline to finish activities that are not pleasant but are necessary to achieve a desired goal. In addition, having self-control also means avoiding making mistakes due to impulsivity, such as jumping to conclusions, saying something without thinking it through, or not calculating the consequences of an action or decision (SCIENTIFIC COMMITTEE OF THE SCIENCE FOR CHILDREN CENTER, 2016, p. 6, translated by us).

Finally, we have Cognitive Flexibility, the third component of FEs, which is related to attentional focus, as well as adaptability and the ability to consider different perspectives to make a decision or rearrange one's thoughts (SEABRA et al., 2014, translated by us). According to the authors, cognitive flexibility is related to creativity, since it suggests that the subject can deal with new situations and act without rigid standards.

For Diamond (2013, p. 149, translated by us), "Cognitive Flexibility also means being flexible enough to adapt to changing demands or priorities, to admit that one has been wrong, and to take advantage of sudden and unexpected opportunities". For its full development, it depends on the development of OM and Inhibitory Control, since to take new perspectives it is necessary to inhibit previously thought forms and analyze a new question inserted in the memory (SCIENTIFIC COMMITTEE OF THE SCIENCE FOR CHILDREN CENTER, 2016).

The FEs are integrated and do not function independently of each other, and the relationships between them help to ensure a more complete learning process. We will now look at the contributions that Cognitive Neuroscience makes to distance higher education.

2.1.4 Contributions of Cognitive Neuroscience to Higher Education: focusing on EaD

Some studies, such as those by Gardner (2000), Andrade and Prado (2003), Silva (2017), among others, describe the contributions of Cognitive Neuroscience to the teaching and learning process of students; however, few have been carried out with higher education students in the distance learning modality as subjects, which makes such

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research extremely necessary.

One of the main points of Neuroscience that should be considered as a contribution to Higher Education is the study of Multiple Intelligences (GARDNER, 2000). According to the author, there are more forms of intelligence than just the quantitative measurement of Intellectual Quotient (IQ), and there are at least nine forms of intelligence: i) Logical-Mathematical; ii) Linguistic; iii) Musical; iv) Spatial; v) Bodily-kinesthetic; vi) Intrapersonal; vii) Interpersonal; viii) Naturalistic; and ix) Existential. This understanding of the multiplicity of forms of intelligence helps programmers and educational designers to build digital platforms to support teachers, facilitators, authors, and EaD supervisors in the teaching and learning process, as well as their students in the learning process, enabling knowledge to be shared in different ways and thus achieving greater assimilation by students.

In this way, Cognitive Neuroscience can help educators create truly productive learning environments that take into account students' multiple intelligences. This is because by creating the right teaching and learning environment, students can more easily and meaningfully acquire the knowledge they need to complete their studies and become qualified professionals.

According to Silva (2017), a subject that doesn't seem to have much to offer can become an enriching and fundamental experience for students, guaranteeing them a satisfactory professional career thanks to the knowledge acquired. For the teacher, this implies a broadening of the range of assessment methods, not limited to a single form of assessment, but allowing the degree of learning and assimilation of each student to be verified in different ways.

Another important perspective pointed out by experts in Cognitive Neuroscience is that synaptic changes are not limited to the developmental period, but occur whenever there is any kind of learning (KANDEL, 2000). This is due to the brain plasticity that underlies the stimuli that promote synapse formation, which occurs throughout life and allows the brain to constantly adapt to new experiences. This brain plasticity manifests itself in actions and behaviors related to learning and memory, highlighting the biological basis of individuality (MOURÃO-JÚNIOR; OLIVEIRA; FARIA, 2017).

Essas pesquisas indicam que os adultos têm a capacidade de aprender em qualquer fase da vida. No entanto, em cada uma dessas fases, são necessários métodos pedagógicos específicos, a fim de proporcionar estímulos diferentes, levando em consideração a individualidade de cada sujeito o que pode ser amplamente realizado nos ambientes da EaD.

This research shows that adults can learn at every

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stage of life. However, at each of these stages, specific pedagogical methods are needed to provide different stimuli, taking into account the individuality of each person.

According to Andrade and Prado (2003), at a certain age (03 to 06 years) the number of synapses between neurons reaches its maximum, which significantly facilitates learning, making it easier, faster, and longer lasting. For the sake of the body's efficiency, unused synapses undergo a process of elimination known as synaptic pruning[1]. It is important to note that the ability to learn is still present, but learning may become slower and more difficult, requiring a greater investment of time and energy in the teaching and learning process.

Therefore, universities and their teachers need to be familiar with students' backgrounds to understand their social and biological aspects. This makes it possible to provide quality teaching that values the individual uniqueness of each student.

2.2 Methodology

This research is a study whose technical procedure was a bibliographic survey. Diez and Horn (2004) state that a bibliographic review aims to search for existing theoretical contributions on a given topic. In the case of this work, the aim is to explore the contributions of Cognitive Neuroscience to Distance Higher Education.

Two databases were searched to find similar research: the Coordination of Superior Level Staff Improvement (CAPES) journal portal and the Scientific Electronic Library Online (SciELO). We used the descriptors neuroscience and distance education and Neuroscience and Remote Learning to filter the research. We also used a time frame of 5 years to target more recent research; it should be noted that the articles collected are all national.

The search on the SciELO portal yielded no results, while the CAPES portal yielded a total of seven results, but only two were relevant to the proposed topic. Based on this obstacle, we extended the search to the ResearchGate[2] platforms, where we found a total of three more studies; Google Scholar[3], where we found two more studies related to the topic under study; and finally, the Semantic Scholar[4] platform, which is an artificial intelligence research platform, where we found one more relevant study.

[1] Synaptic pruning is a process in which synapses that carry information that is not being used gradually weaken and disappear
[2] www. https://www.researchgate.net/
[3] https://scholar.google.com/
[4] https://www.semanticscholar.org/

Using the descriptors mentioned above, two articles were selected for their relevance on the CAPES platform.

Chart 2 - Articles found on CAPES

Articles*	Year	Authors	Thematic
O Fórum e a Aprendizagem Ativa na EAD	2021	ZWICKER, M.R.G.S; SOUSA, K.D; JESUS, R.S SOUZA, L.C; AZEVEDO, R.	The interactivity of forums in distance education and the use of neuroscience as a form of stimulation.
A formação continuada de Professores em tempos da pandemia Do covid-19: Contribuições da Neurociência aplicada à educação	2022	GOMES, L.L; GUIMARÃES, M.H.U; CRUZ, L.H.C	The continuing education of teachers through distance learning with classes addressing the principles of neuroscience and education.

Source: Elaborated by the authors (2023). *The titles of the articles were preserved in Portuguese.

With regard to the ResearchGate platform, we searched especially for articles in Portuguese and available for reading, i. that is, those in which the authors make them available without the need to request them.

Chart 3 - Articles found on ResearchGate

Articles**	Year	Authors	Thematic
A Neurociência e a Educação e Distância: Um Diálogo Necessário	2016	GROSSI, M.G.R; BORJA, S.D.B.	The principles of neuroscience in EaD as a way of improving the student's learning process.
Educação a distância e a Neurociência: Os fatores que encantam os alunos	2019	GROSSI, M.G.R; AGUIAR, F.A; SOUZA,S.D.B; BORJA, S.D.B.	Neuroscience and EaD and empathy with the virtual environment as a way of motivating and stimulating students.
Neurociência, comunicação não violenta e educação a distância: Possíveis aproximações	2020	GROSSI, M.G.R; LEAL, D.C.C.C; ELIAS, M.C.A.S; GROSSI, B.H.R.	Neuroscience and EaD and the use of non-violent communication as a way of keeping students focused on the educational process.

Source: Elaborated by the authors (2023). **The titles of the articles were preserved in Portuguese.

The articles found on Google Scholar deal exclusively with the teacher-student relationship and the principles of remote literacy through the development of cognitive skills.

Chart 4 - Articles found on Google Scholar

Articles***	Year	Authors	Thematic

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Professores e alunos não estavam preparados para o isolamento social e ensino de forma não presencial: e aí, como fica, ficou, tem ficado ou vai ficar?	2021	MARQUES, W.	Student learning in an engineering course through the multiple representations and dialogic relationships of the self and others associated with the assumptions of Neuroscience. And it highlights the teacher-student relationship.
A contribuição da neurociência no processo de alfabetização no ensino remoto	2022	SILVA, J. E. T; MOREIRA, A. S.	The foundation of neuroeducation and the stimulation of phonological awareness with a focus on cognitive development for the acquisition of skills necessary for remote literacy.

Source: Elaborated by the authors (2023). ***The titles of the articles were preserved in Portuguese.

Finally, the article found on Semantic Scholar provides an overview of the inclusion of students with special educational needs and how continuing teacher training, based on the assumptions of Neuroscience, can favor inclusion and the teaching and learning process.

Chart 5 - Articles found on Semantic Scholar

Articles****	Year	Authors	Thematic
Estilos de Aprendizagem e Ensino a Distância na Perspectiva da Inclusão	2018	SOUZA, S.S.S; ARAGON, G.T	The need for planning and continuing teacher training to enable greater access and inclusion for students with special educational needs in order to guarantee their effective inclusion. The study reinforces training in the assumptions of Neuroscience to strengthen teaching and learning.

Source: Elaborated by the authors (2023). ***The title of the article was preserved in Portuguese.

Based on this bibliographic review, it can be said that, although Neuroscience and Distance Education and/or Remote Teaching are currently in evidence, especially in a post-pandemic scenario that has demonstrated the need to use technological resources in the teaching and learning process, in both topics (Neuroscience and Distance Education and/or Remote Teaching) there are still few studies that link them.

Another detail worth mentioning is that, due to the diversity of fields in which Neuroscience operates, the articles found do not focus exclusively on Cognitive Neuroscience, but serve as a basis for new research, whether empirical or

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documentary, in order to broaden studies on this specific branch.

However, since the specificity of Cognitive Neuroscience lies in the analysis of neural mechanisms in the processes of thinking, learning, language and memory, among others (GAZZANIGA, 2018), the analysis of the articles cited above shows that, even without a specific focus, the articles are concerned with the cognitive development of those involved in this teaching and learning process.

2.3 Results and discussion

It is no longer possible to look at Distance Education and/or Remote Teaching without considering the pandemic and how it has directly affected the way we look at Distance Education. In this way, the article “A formação continuada de Professores em tempos da pandemia da COVID-19: Contribuições da Neurociência aplicada à educação” allows us to look at the impact of COVID-19 on teacher training and, consequently, on the way instruction is developed.

The above article shows us that the assumptions of Neuroscience, combined with a mini-course, positively favored the continuing education of teachers, as well as the possibility of aligning technological resources with Neuroscience so that the teaching and learning process takes place efficiently, since for Pantano and Zorzi (2009) it is essential to know the functions of the brain to promote efficient teaching and, consequently, lead to coherent learning.

The article "O Fórum e a Aprendizagem Ativa na EAD" deals specifically with the role of the facilitator at the Virtual University of the State of São Paulo (UNIVESP) and the low frequency of student participation in the forums. The article relates Neuroscience to the contributions of MO, as well as affectivity as a bond for welcoming can favor the construction of knowledge, "[...] learning is a processing resulting from cognitive processes that involve sensation, perception, attention, and memories (operational and long-term)" (PANTANO; ZORZI, 2009, p. 23, translated by us).

The article "A Neurociência e a Educação a Distância: Um Diálogo Necessário" proposes the application of Neuroscience assumptions mediated by technology and concludes that their application depends on the teacher's perception since technologies can facilitate the transmission of knowledge. Pantano and Zorzi (2009) state that the brain learns through the exercise of skills, motivation and repetition, reorganizing and optimizing previous

knowledge, especially with the use of technology and its emerging growth.

The articles "Educação a distância e a Neurociência: Os fatores que encantam os alunos e Neurociência, comunicação não violenta e educação a distância: Possíveis aproximações", since they analyze the contributions of empathy and nonviolent communication in the virtual environment, and that even with the application of neuroscience principles, if there is no motivation and affective bond between teacher and student, as well as clear and welcoming communication, there will gradually be withdrawal and lack of interest in the activity. Cosenza and Guerra (2011) state that emotions and cognition are closely intertwined, so the affective bond provides greater motivation, even in virtual learning environments.

In relation to the article "Professores e alunos não estavam preparados para o isolamento social e ensino de forma não presencial: e aí, como fica, ficou, tem ficado ou vai ficar?", the author contributes to dialogue, the construction of the self and the other, especially in the teacher-student relationship and the need for teachers to reinvent themselves in the pandemic period. The article reports that the use of the principles of Neuroscience, combined with technological tools, can be significant in the teaching and learning process, as well as in the construction of the self and the other and their interrelationship. Amaral and Guerra (2020) state that technology can be a potential factor when used appropriately for the learning process, as well as the way each student emotionally processes information, leading them to more assertive and persistent behavior.

The article "A contribuição da neurociência no processo de alfabetização no ensino remoto" reflects on literacy and the application of neuroscientific assumptions, pointing out that it is possible to learn literacy even in virtual environments, but Amaral and Guerra (2020, p. 118, translated by us) warn that "education must develop students' concentration, self-control, critical thinking, creativity, and healthy interaction skills so that they can make the best use of technology for learning", so it's not just the use of technologies themselves, but the need to see the other as a human being in training who deserves respect.

Finally, the article "Estilos de Aprendizagem e Ensino a Distância na Perspectiva da Inclusão" deals with inclusion and guaranteeing the rights of people with disabilities, as well as obtaining knowledge about neuroscience to provide universal learning design as a factor in combating educational exclusion. The Scientific Committee of the Center of Science for Children (2016) states that the quality of the student's experience, as well as a healthy emotional bond, can be a differentiating factor for the development of executive functions, which directly affect learning and the development of more complex cognitive

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functions, as well as the student's autonomy.

Neuroscience can therefore have a significant impact on the teaching and learning process, especially in virtual environments. It remains clear that teachers need to acquire specific knowledge of both the technological resources available and neuroscience in order to break through the virtual barrier and promote a healthy and motivating learning environment for their students.

3 CONSIDERATIONS

The need to understand how Cognitive Neuroscience can contribute to improving the teaching and learning process in distance education, especially in higher education, has shown that this field of study offers teachers and educational institutions a deeper understanding of how the teaching and learning process takes place. In addition, the analysis of brain plasticity and the understanding of students' synapses help teachers and the whole team involved in the creation of virtual learning environments to make methodological and didactic decisions.

Considering the proposal of this study, and based on the bibliographic research carried out in different databases, it was found that there is a lack of research that addresses the intersection between Cognitive Neuroscience and EaD, especially in the context of Higher Education. This gap highlights the importance and need for studies such as this one, as well as the relevance of empirical research that can provide a more in-depth understanding of the contribution of these fields to the field of higher education.

Therefore, it is clear that in-depth studies that establish a relationship between Cognitive Neuroscience and EaD are very important and necessary. This research will enable teachers to better understand how their students learn and consequently improve their teaching practices, provide quality instruction, and promote meaningful learning.

From this deeper understanding, teachers will be able to adopt more appropriate pedagogical approaches, personalized teaching strategies, and the use of educational technologies that meet the individual needs of students, resulting in a more effective and rewarding learning environment.

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