Cognitive Neuroscience in the Process of Teaching a Second Language in Adulthood: A scope review.

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Abstract. The purpose of this scoping review is to identify and synthesize recent findings in the last five years regarding the relationship between cognitive neuroscience and second language acquisition, showing how brain functions can impact language learning. The methodology used for this research was based on a scoping review carried out on the Eric and Scopus databases. The search resulted in 79 articles, of which 22 were included for analysis. All 22 articles agreed that cognitive neuroscience plays a crucial role in second language teaching, because when both the teacher and the student understand how the brain processes language, this helps to use effective strategies. The research revealed that key factors such as working and long-term memory, along with motivation, play a fundamental role in guiding effective teaching strategies. Activities such as spaced repetition, multimodal learning and emotional support improve language retention. The study concludes that incorporating neuroscientific knowledge into teaching methods can improve language learning for both young people and adults.

Keywords. Cognitive neuroscience, second language, Long term memory, English teaching.

1. Introduction

Neuroscience has advanced significantly in recent decades, providing deep insights into the workings of the human brain, particularly in education and language learning. Cognitive neuroscience, an interdisciplinary field that combines psychology, neurology, biology, and computer science, studies how brain functions support cognitive processes like perception, memory, language, and decision-making. Cognitive neuroscience provides insights that can improve teaching methods for both youth and adult language learners, enhancing traditional educational approaches by revealing how the brain retains new languages and supports cognitive learning(1).

The objective of this work is to portray, through a scope review, the relationship between cognitive neuroscience and second language acquisition process and evidence-based pedagogical practices that have been shown to be effective in language teaching. In the end, it is expected to provide a comprehensive overview of how integrating neuroscientific knowledge into the field of language learning can improve both the student experience and educational outcomes.

Therefore, the main problem that arises in this research are; What is the importance of neuroscience in the educational process? Based on this general question, three specific questions are generated: What is the relationship between neuroscience and learning? How can cognitive neuroscience facilitate teaching practice? What educational practices based on neuroscience can improve the process of teaching and learning English?

2. Methodology

The methodology used for this research was based on a scoping review. The PRISMA Statement guidelines were used for its construction. The search was carried out in the Eric and Scopus databases, using the following keywords: “Cognitive neuroscience of language” AND ´´second language``; ´´Long term memory`` AND ´´English teaching``. Inclusion criteria required that articles be published in English, relate directly to the study's objective, and be from the last five years (2020-2024), and were related to the keywords and the objective of this work published only in English. The exclusion criteria were: EC1- Studies with no access available for viewing or downloading the complete work; EC2- Summarised articles, books, technical reports, dissertations, monographs and works of the same nature and EC3- Studies with irrelevant content in relation to the research domains.

3. Results

An initial search resulted in 79 articles (Eric: 37, Scopus: 42). Following screening, 32 articles were pre-selected: 13 from Eric and 19 from Scopus. Here a total of 47 articles that did not meet the inclusion criteria were excluded: C1- 33; C2-5; C3- 27. In this phase was performed an extraction of information: The information from the studies selected as potential to analyze was recorded and organized in themes types, keyword, purpose, method, year of publication, abstract, keywords, purpose, method discuss and results main recommendations and limitations. Among the 32 articles evaluated through full-text re-view, 10 articles were excluded because they did not meet with the purpose of this research. Finally, 22 articles met the inclusion and exclusion criteria for this review for the narrative synthesis

4. Discussion

The three next topics were the key aspects found related to the link between cognitive neuroscience and second language acquisition.

4.1 The cognitive neuroscience and Language Acquisition

One of the fields of research in cognitive neuroscience is to understand how language is processed in the brain. It is worth noting that in order to successfully acquire a language, several complex processes must take place involving exposure to linguistic input, cognitive processing and executive functions. Understanding how different areas of the brain are involved in language processing can help individuals tailor their language learning strategies(2).

A study carried out by (3), with the objective of exploring how we learn languages, focusing on both first and second language acquisition through the lens of brain science, showed that the importance of understanding how the brain processes language is fundamental to helping students perform better when learning a second language. Indeed, knowing which regions are activated during word recognition or sentence processing can guide teachers and students to focus on specific aspects of language that involve those brain areas.

(3) also highlights that adults have more difficulty learning a new language because brain plasticity, the ability to reorganize and form new connections, decreases with age.

As a result, adults need to focus on language rules and structures, and use cognitive engagement and tailored strategies to enhance learning, unlike in early childhood because they learn more effortlessly . These neurological differences allow educators to adapt language teaching strategies to better suit adolescent and adult learners by using a multidisciplinary approach that includes psychology, linguistics, and cognitive neuroscience (3).

Similarly, research by (4) further supports the role of brain functions in second language acquisition involving a complex network of neural connections and cognitive functions. These key brain processes are: attention, focusing on relevant information while filtering out distractions; encoding, processing and storing new information in memory and consolidation, strengthening neural connections through repeated exposure; and retrieval, recalling and applying learned information from stored memories. Additionally, motivation and emotional engagement play significant roles in how effectively the brain processes and retains new information.

(5) Portray in their study that language processing is mainly controlled by the left hemisphere of the brain, which handles comprehension and production, while the right hemisphere processes prosody (speech rhythm and tone). Both hemispheres contribute to understanding emotional language, with the left hemisphere aiding when prosody affects meaning and the right handling emotional content.

The study used a dichotic listening test, where participants heard word pairs in both ears and repeated what they heard, to examine how the brain processes emotional words. Results showed that the right ear (linked to the left hemisphere) was better at recognizing words, especially positive ones, across both first and second languages, indicating that emotional processing is influenced by language but still primarily relies on the dominant language.

4.2 Key cognitive processes Involved in L2 Learning

Through this search some mental processes were very emphasized which are vital to second language acquisition. These include:

4.1.1 Memory

One of the most cited aspects related to the importance of L2 learning and cognitive neuroscience was memory, because, according to (5) it plays a crucial cognitive process that allows us to store and recall information and skills, which are essential for learning. There are many types of memory, here will be presented the main types of language which are crucial to learn a second language.

Working memory: is a type of memory that temporarily retains and manipulates the information needed for tasks such as understanding language and reasoning, acquiring new words, reading and speaking fluently, linking new information to what is already known. Working memory capacity differs from person to person, which may explain why some students are more successful than others in acquiring a second language (6).

Working memory is divided into two main parts: the phonological circuit, which stores and rehearses speech-based information, and the visuospatial sketchpad, which contains visual and spatial information. Together, these components help individuals to process and retain information effectively, although they are limited in how long they can hold this information without rehearsal (5).

The Central Executive is an important key working memory system that manages how information is processed and stored and avoids distractions. It decides when to store information, what type of information goes to the phonological circuit (responsible for processing and storing speech-based information) or to the visuospatial sketchpad (responsible for temporarily storing and manipulating visual and spatial information.) and how these two types of information work together(2).

Working memory plays an important role in learning a new language because it is crucial for attention and problem-solving tasks. (7) Investigated how the timing of learning a second language (L2) affects brain development and cognitive abilities.

The study found that learning L2 at specific developmental stages can alter how the brain processes sounds and language, leading to improved cognitive control and brain connectivity. The authors also noted that students with poor working memory often struggle with completing tasks, following instructions, and remembering vocabulary. Thus, a key factor is managing cognitive load, which can be reduced by breaking tasks into smaller steps, repeating key information, and using visual aids.

Both authors agree that many teachers may not recognize these challenges, resulting in frustration and inefficiency in the teaching process. These findings suggest that different teaching strategies may be necessary based on when a person starts learning a second language and their previous language experiences, and it is important to understand working memory to improve results.

Long-Term memory (LTM): Long-term memory (LTM) is a type of memory that allows us to store large amounts of information for long periods of time, from minutes to a lifetime. Transforming new information into long-term memory is the main goal of learning a new language. There are two types of LTM:

Explicit: one example is Declarative Memory: This system is responsible for storing facts and meaning, including vocabulary and grammar rules in language learning. In adults, the declarative memory system is more robust than the procedural system, which is one reason why adults tend to rely more on memorizing vocabulary and rules rather than acquiring language intuitively, as children do (8).

Implicit: This involves unconscious memories, like skills and habits. One example is Procedural Memory which is involved in the automatization of skills, related to the process of learning rules and sequences and syntax in conversation, they are processed in different brain regions. In children, procedural memory plays a more significant role in language acquisition, but adult learners can still develop automaticity with practice and repetition (8).

(9) Examined how these memory systems interact in language learning. The study found that learning regular forms of the past tense uses procedural memory when learners receive metalinguistic cues, while learning irregular forms relies more on declarative memory with recasts (correct forms given as feedback). This supports the idea that integrating explicit knowledge with repeated practice is vital for effective language learning and fluency.

Thus, to store information in long-term memory two stages have to be considered: Encoding: Converting sensory information into a form the brain can store, Consolidation: occurs after encoding, mainly in the hippocampus plays a central role by integrating sensory inputs and turning short-term memories into long-term ones. Sleep, especially deep sleep and REM phases, is vital for this process (8).

4.1.2 Emotional and Motivational Factors

Motivation and emotion are essential parts critical in second language learning, with the brain's reward system and emotional state directly influencing success. Dopamine release, triggered by achievements in language learning (mastering a phrase or

understanding a text), reinforces motivation by rewarding learners for progress. Positive emotions are also linked to better learning outcomes, while stress and anxiety can hinder memory and attention. This is why teachers need to always find ways to show students how they are evolving (10).

The limbic system, responsible for emotion, affects how motivated a person is to learn a new language. Positive emotional experiences enhance dopamine release, boosting memory and learning capabilities. Adult and teenage learners often face emotional challenges like fear of making mistakes or feeling self-conscious, which can hinder progress. Creating supportive, low-stress learning environments can help overcome these barriers and enhance language acquisition. Teachers who foster a supportive and encouraging learning environment can help mitigate these negative effects, allowing learners to engage more fully with the material (10).

(11) Explored how motivation and vocabulary learning strategies (VLS) influence vocabulary acquisition among Korean adolescents learning English. Their study found that motivation, especially intrinsic motivation, has a significant impact on both VLS use and vocabulary knowledge. Intrinsic motivation proved to be a stronger predictor than extrinsic motivation.

These authors agree that enhancing motivation and teaching effective vocabulary strategies can improve vocabulary size and depth, especially by fostering supportive and challenging learning environments.

4.3 Cognitive neuroscience and language teaching strategies

Spaced repetition

Since Declarative memory plays a major role in adult language learning, spaced repetition, a technique where information is revisited at increasing intervals, is indispensable for storing information in long-term memory. It is particularly effective in transferring new knowledge into long-term memory, while retrieval practice (actively recalling information) further strengthens retention (12).

(12) Examined the use of spaced repetition in vocabulary acquisition among Ukrainian-speaking ESL students. They created seven mobile-friendly audio lessons to help students learn and retain 120 English words. The study found that students using spaced repetition not only performed better in learning new words but also experienced less stress. Also, the use of audio resources was highlighted as a valuable tool for enhancing vocabulary learning.

Similarly, (13) compared spaced learning with massed learning (cramming) among Iranian students learning home-related vocabulary. Students exposed to vocabulary consistently through spaced repetition outperformed those who learned all at once in both immediate and long-term recall.

Both studies confirm that spaced learning is more effective for vocabulary retention than cramming. This aligns with earlier research (Ebbinghaus) that shows distributed study sessions lead to better understanding and memory retention over time.

Multimodal learning

Engaging multiple senses (visual, auditory, and kinesthetic) enhances language retention by stimulating different neural pathways, making learning more effective. Teaching language involves both direct strategies (memory, cognitive, and compensation) for immediate learning, and indirect strategies (metacognitive, affective, and social) that support overall learning processes like planning and managing emotions (14).

A study (15) found that metacognitive and compensation strategies were most used by EFL students, suggesting that using the right language learning strategies (LLS) improves both effectiveness and enjoyment in language acquisition. 15) Further showed that physical exercise before language learning improved mood and vocabulary retention, suggesting that combining movement with learning boosts cognitive outcomes.

(16) Demonstrated that intrinsic motivation (IM), refers to engaging in a behavior because it is inherently enjoyable, satisfying, or interesting, is more effective than extrinsic motivation (EM), which involves engaging in a behaviour in order to earn a reward or avoid a punishment, in vocabulary learning. Teachers foster IM by creating engaging environments and guiding self-regulated learning, for example: solving puzzles or reading an interesting book they might like .

(17) Proposed a more accurate method for assessing reading difficulty using advanced language models, which could help teachers select appropriate learning materials. Their study also emphasized the potential of Long Short-Term Memory (LSTM) networks in tracking student progress, allowing teachers to offer real-time feedback based on behavioural data, particularly in online learning environments.

Error Correction and Feedback

Adult learners often benefit from explicit feedback on errors, a practice supported by cognitive neuroscience research. When feedback is delivered in a timely manner, it allows the brain to update its mental model of the language, leading to more accurate performance over time.

Corrective feedback (CF) is a response given to learners when they make errors, and it plays a crucial role in helping them improve their language skills. There are three types of CF: recasts, which involve the teacher rephrasing a student's incorrect statement; explicit correction, where the teacher directly tells the student what was wrong; and prompts, which encourage students to think and find the correct answer themselves without providing it outright (SATO, 2023)(18).

The study, based on (9), examined how corrective feedback CF influences learning regular and irregular past tense forms. It was focused on metalinguistic prompts, which give hints or clues to help students retrieve the correct forms from their existing knowledge, rather than simply providing the correct answers. It found that the amount of CF received was similar across feedback types (recasts, explicit correction, and metalinguistic prompts) for both regular and irregular past tense forms.

They also discussed the impact of corrective feedback (CF) on second language (L2) learning, emphasizing that its effectiveness depends on individual learner factors like cognitive abilities and memory types. It distinguishes between declarative memory (for facts and experiences) and procedural memory (for skills and habits) and explores how these relate to different CF types, such as recasts, explicit corrections, and metalinguistic prompts.

Active engagement
Language learning is a gradual process, requiring learners to gather, store, recall, and use information. To make students actively engage in this process is essential to activate their brain process rather than passive studying. Language Learning Strategies (LLSs), especially metacognitive strategies (choosing and applying the right techniques for different situations), play a key role in improving language skills. Teaching students how to select and use these strategies is essential for successful language acquisition (19).

(19) Conducted research at a Mexican agricultural high school to identify the Vocabulary Learning Strategies (VLSs) of 107 elementary English students. The study found that students used VLSs at a medium level, with common strategies including identifying new words and predicting meanings from context. However, many struggled with reviewing vocabulary. The research highlights the importance of teaching metacognitive strategies to help students improve their learning techniques.

(20) Explored the effectiveness of incidental learning in language acquisition through film viewing. Their research demonstrated that watching films helped learners practice reading and listening skills, as well as develop the ability to express thoughts and opinions about the films. By engaging in activities like film reviews, participants enhanced their overall language proficiency. The study used both closed questions (e.g., yes/no, multiple choice) and open-ended questions to assess comprehension, showing that films can be an effective tool for improving language skills.

Cognitive flexibility,
Cognitive flexibility or the ability to switch between languages and manage interference from one's native language (L1), can be improved through brain training activities like memory games or puzzles. This skill is critical for second language (L2) learning (21).

(21) Explored how inhibiting L1 helps in learning a second language in the article "Native Language Inhibition Predicts More Successful Second Language Learning." English-speaking learners of Spanish completed phrases under varying difficulty, where "easy" tasks had unrelated distractors and "difficult" tasks required avoiding English words that were incorrect in Spanish. The study concluded that L1 inhibition is crucial for successful L2 learning, and practicing in difficult situations enhances acquisition.

(22) Explored how varying levels of involvement in learning tasks, defined by "need," "search," and "evaluation," affect vocabulary retention. Based on the Involvement Load Hypothesis (ILH). The study found that higher cognitive effort leads to better vocabulary acquisition.

The research focused on the effects of dual subtitles (showing both the learner’s first language, L1, and the target language, L2) on English vocabulary learning among 72 Chinese-speaking low-intermediate EFL learners. Tasks with higher involvement, such as guessing word meanings and writing about videos, resulted in better immediate and long-term vocabulary retention.

5. Conclusion

Cognitive neuroscience can provide valuable insights into how adults learn a second language, offering a roadmap for overcoming the challenges inherent in adult language acquisition. By understanding the cognitive processes involved in such as memory systems, executive function and motivation and emotion in language learning by using techniques such as spaced repetition, multimodal learning and social engagement, educators can design more effective language programs for adult learners. It is worth noting that most of the articles showed the great importance of technology in this process, suggesting that it is essential for teachers to study and use these tools more when teaching, in order to make this process enjoyable. Furthermore, it was not possible to delve into each of the key points of this study, which may make further research into how short-term memory is transformed into long-term memory necessary, in order to find more tools to help in this very important process.

6. References

[1] Cearon IF, de Moraes Feltes HP. Neuroscience role in the foreign language teaching and learning. *Ciências & Cognição*. 2020; 13;25(1):43-60.

[2] Del Maschio N, Sulpizio S, Abutalebi J. Thinking outside the box: The brain-bilingualism relationship in the light of early neurobiological variability. *Brain and Language*. 2020 Dec 1;211:104879.

[3]Aktan-Erciyes A. Understanding language acquisition: Neural theory of language. Journal of *Language and Linguistic Studies.* 2021 Jul 1;17(2):697-705.

[4] Wedlock J, Binnie C. Selecting and using authentic videos for intentional second language learning: nine considerations. *English Australia Journal.* 2023 Apr 1;39(1):24-40.

[5]Ibarra Santacruz D, Hidalgo Dávila HA, Silvana Paredes Castillo E. Games for Working Memory Training in Foreign Language Learning. *Mextesol Journal.* 2020;44(4):n4.

[6]Heyrani R, Nejati V, Abbasi S, Hartwigsen G. Laterality in emotional language processing in first and second language. *Frontiers in Psychology.* 2022 Feb 3;12:736359.

[7]Kousaie S, Chen JK, Baum SR, Phillips NA, Titone D, Klein D. Bilingual language experience and the neural underpinnings of working memory. *Neuropsychologia*. 2021 Dec 10;163:108081.

[8]Tang Y, Luo S. Possibilities and Caveats of Implicit Language Aptitude Measurements. *Language Teaching Research Quarterly.* 2022;31:119-35.

[9]Sato, Yusuke. "Interactions among declarative and procedural memory systems, different linguistic structures, and the efficacy of different corrective feedback types." *Journal for the Psychology of Language Learning* 5.1 (2023): 1-16.

[10]Çetin Ç, Bölükbasi Macit Z. The Mediating Role of Cognitive Flexibility between Foreign Language Learning Motivation and Foreign Language Anxiety of University Preparatory School Students. *International Online Journal of Education and Teaching.* 2022;9(3):1167-80.

[11]Lee, Jang Ho, Joung Joo Ahn, and Hansol Lee. "The Role of Motivation and Vocabulary Learning Strategies in L2 Vocabulary Knowledge: A Structural Equation Modeling Analysis." *Studies in Second Language Learning and Teaching* 12.3 (2022): 435-458.

[12] Zubenko, Tetiana, et al, 2022 "SPACED VOCABULARY ACQUISITION WHILE INCIDENTAL LISTENING." *Advanced Education* (2022): 79-87.

[13] Namaziandost E, Hosseini E, Utomo DW. A comparative effect of high involvement load versus lack of involvement load on vocabulary learning among Iranian sophomore EFL learners. Cogent Arts & Humanities. 2020 Jan 1;7(1):1715525.

[14] Girón-García C, Gargallo-Camarillas N. Multimodal and perceptual learning styles: Their effect on students' motivation in a digital environment. *The EuroCALL Review,* 28 (2), 23-38.

[15]Rahman, Mohammed Mahib UR. "EFL learners' language learning strategies: a case study at Qassim university." *Advances in Language and Literary Studies* 11.5 (2020): 6-11.

[16] Birdsell, Brian J. "Exercising before Learning Enhances Long-Term Memory for Foreign Language Vocabulary and Improves Mood." *Journal for the Psychology of Language Learning* 5.1 (2023): e5112123.

[18] Wang Y, Zhou J, Li Z, Zhang S, Han X. Automatically difficulty grading method for English reading corpus with Multi-feature Embedding based on Pre-trained Language Model. *IEEE Transactions on Learning Technologies.* 2023 Sep 26.

[19]Logojan, Anamaria Aurelia. "Vocabulary Learning Strategies Used by Elementary-Level Students of English." *Mextesol Journal* 45.2 (2021): n2.

[20]Senguttuvan M, Tomy P, Baisel A, Vijayakumar M. Movie Reviewing-A Prospective Incidental Learning Approach in English Language Acquisition. *Studies in Media and Communication.* 2022;10(2):99-104.

[21] Pulido MF. Native language inhibition predicts more successful second language learning: Evidence of two ERP pathways during learning. *Neuropsychologia.* 2021 Feb 12;152:107732.

[22] Lo S. Learning vocabulary through dual-subtitled viewing: the impact of different ILH-based interventions. *Computer Assisted Language Learning.* 2022 Sep 19:1-28.