



## **Brainwave signals of language learning anxiety: A systematic review of EEG studies and Its Contributions to ELT**

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### **Abstract**

Language learning anxiety poses a significant challenge for English Language Teaching (ELT) in Indonesian education; however, traditional methods frequently neglect its neurophysiological foundations. Therefore, it is imperative to investigate learning anxiety through EEG-based brainwave monitoring. This review study examines how EEG assessments identify specific brainwave types, brain regions, and treatments for learning anxiety. A systematic literature review (SLR) approach adhered to PRISMA guidelines. The flow diagram results indicate that out of 250 articles identified from Scopus-indexed journals, 140 passed the initial screening stage, 90 were selected for further review, and only 30 met the inclusion criteria. These articles were categorized into three main themes: brainwave types, brain regions, and EEG treatment for anxiety. The findings indicated that EEG studies consistently and accurately detect learning anxiety through increased beta wave activity and decreased alpha and theta wave activity, particularly in the prefrontal cortex, which is linked to cognitive stress and emotional regulation dysfunction. Additionally, significant brain activation was observed in the frontal, prefrontal, parietal, and temporal regions, as well as in the limbic system. EEG-based interventions, such as neurofeedback and vagus nerve stimulation, were also found to be effective in reducing anxiety through non-pharmacological means. However, current research is still limited to experimental studies conducted in laboratory settings, which do not fully capture the dynamic nature of learning anxiety in real classroom contexts for better input of teaching strategies. The study implies that English language teaching should incorporate neuroscience-informed, anxiety-reducing strategies, providing practical insights for teachers to adapt instructional techniques and improve learning outcomes.

**Keywords:** brainwave signals, EEG studies, language learning anxiety, cognitive neuroscience

### **Abstrak**

*Kecemasan belajar bahasa merupakan tantangan yang signifikan dalam pendidikan di Indonesia; namun, metode tradisional sering kali mengabaikan dasar neurofisiologisnya. Oleh karena itu, penting untuk mengkaji kecemasan belajar melalui pemantauan gelombang otak berbasis EEG. Studi tinjauan ini menelaah bagaimana asesmen EEG mengidentifikasi jenis gelombang otak tertentu, wilayah otak, serta bentuk penanganan terhadap kecemasan belajar. Pendekatan Systematic Literature Review (SLR) dilakukan dengan mengikuti pedoman PRISMA. Hasil diagram alur menunjukkan bahwa dari 250 artikel yang teridentifikasi dari jurnal terindeks Scopus, 140 lolos tahap penyaringan awal, 90 dipilih untuk ditinjau lebih lanjut, dan hanya 30 yang memenuhi kriteria inklusi. Artikel-artikel tersebut dikategorikan ke dalam tiga tema utama, yaitu jenis gelombang otak, wilayah otak, dan penanganan kecemasan berbasis EEG. Temuan menunjukkan bahwa studi EEG secara konsisten dan akurat mendeteksi kecemasan belajar melalui peningkatan aktivitas gelombang beta serta penurunan aktivitas gelombang alfa dan theta, khususnya pada korteks prefrontal yang berkaitan dengan stres kognitif dan disfungsi regulasi emosi. Selain itu, aktivasi otak*

*yang signifikan juga teramati pada wilayah frontal, prefrontal, parietal, dan temporal, serta pada sistem limbik. Intervensi berbasis EEG, seperti neurofeedback dan stimulasi saraf vagus, juga terbukti efektif dalam mengurangi kecemasan melalui pendekatan non-farmakologis. Namun, penelitian yang ada saat ini masih terbatas pada studi eksperimental yang dilakukan di lingkungan laboratorium, sehingga belum sepenuhnya menangkap dinamika kecemasan belajar dalam konteks kelas yang nyata sebagai dasar pengembangan strategi pembelajaran yang lebih tepat. Studi ini mengimplikasikan bahwa pengajaran bahasa Inggris perlu mengintegrasikan strategi berbasis neurosains yang berorientasi pada pengurangan kecemasan, serta memberikan wawasan praktis bagi guru untuk menyesuaikan teknik pembelajaran guna meningkatkan hasil belajar siswa.*

**Kata kunci:** *sinyal gelombang otak, studi EEG, kecemasan belajar Bahasa, neurosains kognitif*

## **Introduction**

Language learning anxiety (LLA) refers to feelings of tension, worry, and apprehension that arise specifically during the process of learning or using a new language, particularly in situations such as speaking, testing, or performing tasks (Chow et al., 2021). Neurologically, anxiety is associated with autonomic nervous system arousal during tests and performance tasks, and may manifest as trait, state, or situation-specific anxiety (Wang et al., 2019). It is defined as an unpleasant emotional reaction experienced during learning, often accompanied by phobic symptoms (Piccolo et al., 2017). From a cognitive neuroscience perspective, learning anxiety alters cognitive processing and physiological responses by disrupting neural connectivity in brain regions related to attention, memory, and emotional regulation (Edwards et al., 2023). As a neuropsychological response, it can be objectively observed through brainwave activity recorded using electroencephalography (EEG). Therefore, it is important to study LLA from a neuroscientific perspective because it not only affects learners' emotions but also disrupts brain functions related to attention, memory, and emotional regulation, and can be objectively measured through EEG brainwave patterns, allowing for more accurate identification and effective, evidence-based interventions to reduce anxiety in language learning contexts.

EEG is a non-invasive technique that records the brain's electrical activity via scalp electrodes and has been widely used in both medical and cognitive research (da Silva, 2022). It enables the identification of wave patterns—such as alpha, beta, theta, and gamma associated with emotional and cognitive states. Empirical findings indicate that EEG can differentiate anxiety-related brainwave patterns from normal conditions and analyze changes in attention control and performance monitoring (Tasyakuranti et al., 2022). In particular, increased beta activity and reduced alpha–theta activity have been reported as potential neural biomarkers of anxiety (Aristizabal et al., 2024). Despite these advances, research specifically investigating learning anxiety through EEG remains limited, particularly in developing countries such as Indonesia. There is a lack of systematic synthesis mapping brainwave patterns, associated brain regions, and EEG-based interventions in educational contexts. Therefore, this systematic literature review aims to synthesize existing evidence on how EEG detects neural signatures of learning anxiety, identifies affected brain areas, and evaluates the

potential of neurofeedback-based interventions to reduce anxiety in learning environments.

1. How do EEG studies identify the brain wave signals of students' learning anxiety?
2. How can EEG determine the brain area exhibiting students' learning anxiety?
3. Is the treatment of Neurofeedback EEG effective in reducing learning anxiety?

### **Review of Literature**

This systematic literature review (SLR) contributes to the advancement of neuroeducation by integrating neurological and educational perspectives in understanding learning anxiety. Neuroeducation provides a framework for examining learners' emotional states through brainwave patterns that indicate anxiety and its potential treatment. This review synthesizes two core domains: (1) neurological theories and empirical evidence on learning anxiety, and (2) the role of electroencephalography (EEG) in identifying anxiety-related brainwave patterns and informing technology-based interventions. In addition, this review is grounded in several theoretical frameworks, including Affective Filter Theory, Cognitive Load Theory, Attentional Control Theory, and Neurobiological Models of Anxiety, which collectively explain the interaction between emotion, cognition, and brain activity in language learning.

### **Learning Anxiety**

In EFL/ESL contexts, learning anxiety has been widely conceptualized within psychological and cognitive frameworks. Foreign Language Anxiety (FLA) significantly hinders language acquisition and may arise from unfamiliar vocabulary, complex syntax, and cultural differences (Horwitz et al., 2010); This concept is strongly supported by the Affective Filter Theory (Krashen. & Terrell, 1983). The natural approach. San Francisco, CA: Alemany Press., which posits that emotional variables such as anxiety act as a mental barrier that prevents language input from being effectively processed and acquired.

From a cognitive perspective, Cognitive Load Theory explains that anxiety increases extraneous cognitive load, thereby diverting mental resources from meaningful learning processes to emotional regulation (Zhang & Zou, 2023); Furthermore, Attentional Control Theory suggests that anxiety impairs the balance between goal-directed and stimulus-driven attention, leading to reduced concentration and inefficient language processing (Ehrlich, 2020).

From a neuroscientific standpoint, these theories are supported by Neurobiological Models of Anxiety, which explain how anxiety affects brain function. Learning involves distributed brain regions, including the left inferior frontal gyrus, temporoparietal areas, and occipitotemporal cortex (Ryherd et al., 2018). Anxiety disrupts these processes by increasing amygdala activity, associated with emotional responses and weakening the regulatory function of the prefrontal cortex (Mogg & Bradley, 2016). Excessive anxiety also impairs the dorsolateral prefrontal cortex, reducing working memory efficiency and increasing cognitive overload (Spalding, 2021) These interactions reflect dysregulation between the prefrontal cortex and the limbic system, which ultimately reduces learning efficiency.

### ***Electroencephalography (EEG) Technique***

EEG has become a key method for examining the neural mechanisms underlying learning anxiety due to its high temporal resolution and ability to capture real-time neural activity (Luck, 2014). EEG studies typically analyze frequency bands such as alpha (8–12 Hz), beta (13–30 Hz), theta (4–7 Hz), and gamma (>30 Hz), each associated with distinct cognitive and emotional processes (Schürmann & Başar, 2001). Within the framework of **Neurocognitive Theory**, these brainwave patterns reflect underlying cognitive states, including attention, memory load, and emotional arousal.

Learning anxiety is generally characterized by increased beta and theta activity and decreased alpha activity, reflecting heightened cognitive effort and reduced attentional control (Shine et al., 2023). Event-related potentials (ERPs), such as N400 and P600, provide further insights into lexical access and syntactic processing under anxiety (Rajkumar, 2024). These findings align with Information Processing Theory, which explains how disruptions in neural processing stages can impair comprehension and language performance.

Power spectral density and coherence analyses reveal disruptions in functional connectivity, particularly between the prefrontal cortex and limbic system (Li et al., 2015). Empirical findings indicate that anxious learners exhibit increased frontal theta activity and altered amygdala–prefrontal connectivity, suggesting working memory strain and emotional regulation demands. Delayed N400 and reduced P600 responses further demonstrate impaired lexical and syntactic processing (Zaharchuk et al., 2021) et al., 2021). Complementary eye-tracking and fMRI studies corroborate these findings, revealing cognitive overload, hyperactive amygdala responses, and reduced prefrontal engagement (Mihajlović et al., 2015).

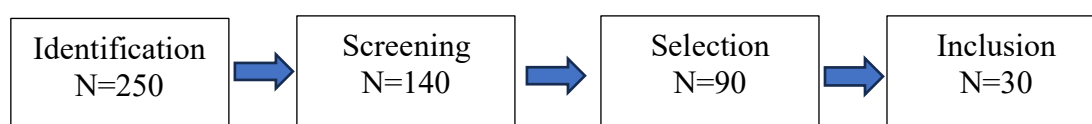
Overall, the reviewed literature highlights EEG’s capacity to detect neural signatures of learning anxiety and underscores the importance of integrating affective, cognitive, and neurobiological theories in understanding language learning processes. By combining these theoretical perspectives, this review provides a comprehensive framework for interpreting how anxiety influences both brain activity and learning outcomes. This review aims to map and synthesize EEG-based evidence on brainwave localization, neural activity patterns, and methodological approaches, providing a foundational reference for future research, particularly in contexts such as Indonesia where EEG-based investigations of learning anxiety remain limited.

### **Method**

This study employed a Systematic Literature Review (SLR) to examine theoretical and empirical evidence on brainwave patterns associated with learning anxiety as measured through electroencephalography (EEG). The review followed PRISMA guidelines to ensure transparent selection, appraisal, and synthesis of relevant studies (Parums, 2021). The review focused on identifying neurological indicators of learning anxiety, including brain localization, dominant brainwave patterns, and EEG mechanisms. The SLR approach was chosen due to the limited EEG-based language learning research in Indonesia and disparities in EEG studies across regions.

The procedure included formulating research questions, establishing inclusion and exclusion criteria, conducting a systematic search, screening studies, extracting data, appraising quality, and synthesizing findings (Kitchenham et al., 2009). In EEG-based systematic reviews, studies are typically selected based on criteria such as relevance to EEG measurements of anxiety, use of empirical research designs, clarity in reporting brainwave patterns and brain regions, methodological rigor, publication within a defined time range, and accessibility of full-text articles. Eligible studies were empirical articles published in English (2005–2025) that investigated learning anxiety using EEG in student populations.

Non-empirical and unrelated studies were excluded. Literature searches were conducted in PubMed, Scopus, and Google Scholar, supported by Publish or Perish, using keywords such as “EEG,” “learning anxiety,” and “brain wave.” Selected studies were categorized into three themes: brainwave patterns, brain localization, and EEG-based interventions. The selection process is illustrated in the PRISMA flow diagram (Figure 1).



**Figure 1.** A PRISMA flow diagram

During the screening phase, duplicate records were removed, followed by title and abstract screening and full-text review to ensure compliance with the inclusion criteria. The number of excluded studies at each stage was documented in the PRISMA flow diagram.

From an initial pool of 200 articles retrieved from three indexed databases, 140 were retained after preliminary screening. Of these, 90 articles were further reviewed and grouped into three thematic categories. Ultimately, 30 articles from Scopus-indexed journals met all criteria and were included in the final analysis. The quality appraisal of these studies, conducted using the Critical Appraisal Skills Programme (CASP), is summarized in Table 1.

Table 1. Quality of assessment

QA	Questions
Q1	Did the article align with the learning anxiety in EEG analysis?
Q2	Did the article explain the brain wave signals of anxiety?
Q3	Is the title relevant to the present study?
Q4	Did the authors have a clear analysis of the precise region indicating anxiety?
Q5	Are the overall results of the study related to EEG analysis in learning anxiety?
Q6	Is the articles within 2005-2025?

The subsequent stage involves assessing the quality of each selected study to determine its validity, reliability, and relevance to the research objectives. To maintain

consistency and methodological rigor, multiple reviewers conducted the assessment using the Critical Appraisal Skills Programme (CASP) checklist. This tool is divided into three core sections: (1) assessing the appropriateness and validity of the study, (2) identifying key research findings, and (3) evaluating the study's contextual contribution. Each section consists of ten questions answered with "Yes," "No," or "Can't tell." A comprehensive Quality Assessment (QA) process was applied to ensure that all included studies met the established standards. The results of this assessment, based on the CASP checklist, are presented in Table 2.

Table 2. The results of the article selection with CASP checklists.

No	Scopus Indexed Title	Authors	Questions						Validity	
			Q1	Q2	Q3	Q4	Q5	Q6	Yes	No
1	<i>Learning curves of theta/beta neurofeedback in children with ADHD</i>	Janssen, T. (2017).	√	-	-	-	-	√		√
2	<i>Machine Learning for Anxiety Detection Using Biosignals: A Review</i>	Ancillon, L. (2022).	√	√	√	√	√	√	√	√
3	Comparative analysis of physiological signals and electroencephalogram (EEG) for multimodal emotion recognition using generative models	Mailhot, T. (2018). Torres-Valencia, C.A. (2015)	√	√	√	√	√	√	√	√
4	<i>An electroencephalographic signature predicts antidepressant response in major depression.</i>	Wu, W. (2020).	-	-	-	√	-	√		-
5	...									

For data analysis, a qualitative meta-synthesis approach was adopted, incorporating meta-aggregation and meta-ethnography to summarize results and develop new conceptual insights. A thematic analysis was conducted to categorize the findings based on EEG wave patterns (alpha, beta, theta) and brain localization of anxiety-related activity (e.g., prefrontal cortex, amygdala). This triangulated analytical method supports both the theoretical interpretation and practical application of EEG research in addressing students' learning anxiety.

## Result and Discussion

### *The brain wave signals of students' learning anxiety*

The findings demonstrate that EEG effectively detects brainwave patterns associated with language learning anxiety by measuring neural activity during academically stressful tasks. Anxiety is commonly reflected in specific frequency bands: increased beta activity (13–30 Hz), decreased alpha power (8–13 Hz), and elevated theta activity (4–8 Hz). Heightened beta waves in the prefrontal cortex

indicate stress and hyperarousal (Khosrowabadi et al., 2011), while reduced alpha activity corresponds to diminished relaxation (Jaiswal et al., 2019). Increased theta activity suggests difficulties in emotional regulation and working memory (Putman et al., 2014). EEG studies employ resting-state, task-based, and event-related potential (ERP) paradigms, with analytical techniques such as Fast Fourier Transform (FFT) and Independent Component Analysis (ICA) to quantify anxiety-related neural signals (Wei et al., 2020).

From Scopus-indexed studies published since 2005, ten articles were identified as most relevant to the relationship between learning anxiety and brainwave patterns. Research indicates that anxiety modulates beta-band oscillations, biasing neural prediction processes and impairing learning (Hein & Herrojo Ruiz, 2022). High detection accuracy has been reported, particularly when EEG is combined with physiological measures such as electrodermal activity and heart rate (Ancillon et al., 2022). Detection models have achieved accuracy rates between 94% and 97% using advanced analytical approaches (Ramani et al., 2022); Additionally, alpha/beta and theta/beta power ratios, as well as frontal alpha asymmetry, have been consistently linked to anxiety levels (Munteanu & Munteanu, 2019).

Regarding interventions, EEG-based neurofeedback has shown strong potential in reducing anxiety. Alpha/theta training enhances relaxation and emotional regulation (Gruzelier, 2009), while modifying alpha and low-beta activity has reduced anxiety symptoms in younger populations (Heinrich et al., 2007). Delta–beta coupling measures further distinguish trait and state anxiety (Apicella et al., 2022). Complementary non-pharmacological approaches, such as yoga, have also been shown to increase alpha and theta activity associated with relaxation (Desai et al., 2015).

Overall, the evidence indicates that increased beta activity, reduced alpha and theta power, and frontal asymmetry are robust neural markers of learning anxiety. Power ratios and connectivity measures consistently correlate with anxiety levels and can be reliably detected through EEG analyses. Beyond diagnosis, EEG-based neurofeedback and integrative interventions offer promising avenues for managing learning-related anxiety and emotional dysregulation.

### ***The Brain Areas Associated with Students' Learning Anxiety***

Empirical studies using electroencephalography (EEG) consistently show that learning-related anxiety is reflected in distinct activation patterns across the frontal, prefrontal, parietal, temporal, and limbic regions. Multichannel EEG combined with deep learning has accurately identified anxiety-related negative emotions, particularly in the frontal and temporal areas (Shen et al., 2020). Abnormal functional connectivity in the prefrontal and parietal cortices has also been used to classify social anxiety disorder (Al-Ezzi et al., 2020) while spectral power and connectivity measures have proven effective in detecting neuropsychiatric conditions, including anxiety (Parsa et al., 2023).

Frontal EEG asymmetry has been shown to correlate with anxiety tendencies, underscoring the role of anterior brain regions in processing negative emotions (Kuper et al., 2019) Research further indicates that heightened cognitive load during language tasks increases beta activity and decreases alpha power in frontal and parietal cortices, reflecting elevated stress responses. Abnormal frontal activity has also been observed

in children with learning disorders linked to anxiety (Hobson & Pace-Schott, 2002). Moreover, mindfulness and neurofeedback interventions have demonstrated measurable changes in prefrontal and amygdala activity, supporting EEG's role in monitoring emotional regulation ((Gerber & Matuschek, 2023).

Recent advances highlight the predictive role of the prefrontal cortex through theta and alpha synchronization (Knyazev et al., 2005). Machine learning approaches applied to EEG data further enhance anxiety classification accuracy, particularly within frontal and parietal regions and across alpha, beta, and theta bands (Aldayel & Al-Nafjan, 2024). Real-time frontal neurofeedback has also been shown to significantly reduce anxiety by directly training emotional regulation (Kishore Kanna et al., 2024)

Overall, the evidence confirms that the prefrontal, parietal, and temporal regions are central to learning anxiety, and that EEG; supported by spectral analysis and machine learning, offers strong potential as both a diagnostic and intervention tool for student anxiety.

### ***Treatment of Learning Anxiety Using EEG Techniques***

Research on EEG-based treatment of learning anxiety shows a growing emphasis on non-invasive and neurophysiological interventions, including sleep-based approaches. Sleep disturbances and circadian rhythm disruption have been linked to altered theta and delta activity that may exacerbate anxiety, with sleep management shown to reduce chronic symptoms (Chellappa & Aeschbach, 2022). Supporting this, (Takada et al., 2017) found that *Lactobacillus casei* improved sleep quality and normalized stress-related EEG disruptions.

Direct central nervous system interventions have also demonstrated effectiveness. Aromatherapy massage has been shown to increase alpha activity and reduce cortisol levels (Wu et al., 2014), while non-invasive vagus nerve stimulation decreases amygdala activity and enhances emotional regulation (Bremner et al., 2020). Pharmacological modulation of neural activity, such as calcium channel regulation, has likewise been associated with anxiety reduction (Owen, 2007).

Neuropsychiatric evidence further indicates that abnormal EEG patterns such as slowing, triphasic waves, elevated gamma, and increased frontal delta, are linked to anxiety-related cognitive and emotional dysfunction (Kaplan & Rossetti, 2011). The regulatory role of the prefrontal cortex is also supported by findings on serotonin 5-HT<sub>2A</sub> receptor involvement in emotion modulation, alongside neuroimaging evidence demonstrating altered prefrontal activation in anxiety-related conditions (Aznar & Klein, 2013)

Overall, the literature suggests that interventions targeting EEG patterns, whether biological (e.g., probiotics, pharmacology), psychophysiological (e.g., vagus nerve stimulation, aromatherapy), or behavioral (e.g., sleep regulation), hold substantial promise for reducing learning anxiety. An integrative approach combining EEG monitoring with multimodal therapies may provide an effective strategy for managing anxiety that interferes with learning performance.

## **Discussion**

This review identified three key themes: (1) brainwave patterns associated with anxiety, (2) localization of anxiety-related brain regions, and (3) EEG-based neurological interventions.

First, learning anxiety is consistently characterized by increased beta activity and decreased alpha and theta activity, particularly in the prefrontal region, along with frontal alpha asymmetry (Apicella et al., 2022; Gruzelier, 2009). These patterns reflect heightened cognitive stress and reduced emotional regulation during learning tasks. Although EEG reliably detects these neural markers, most studies remain laboratory-based, limiting ecological validity (García-Monge et al., 2024). Research integrating EEG with affective variables such as motivation and self-confidence—especially in foreign language learning and longitudinal studies linking brainwave patterns to academic performance remain scarce (Bennett, 2018). Thus, while EEG effectively identifies neural correlates of learning anxiety, translating these findings into neuroscience-informed educational interventions remains a critical gap.

Second, anxiety-related activation predominantly involves the frontal, prefrontal, parietal, temporal, and limbic regions (Bagheri & Power, 2020; Dehghani et al., 2023). Frontal asymmetry and abnormal connectivity patterns are key indicators, increasingly supported by spectral analysis and deep learning classification. However, EEG research on English as a Foreign Language (EFL) learners and younger students is limited. Few studies provide detailed brain topography mapping necessary for targeted neurofeedback interventions (AlShorman et al., 2020), and authentic classroom-based research remains rare. Findings indicate that learning anxiety involves activation in the frontal, prefrontal, parietal, temporal, and limbic regions, with frontal asymmetry and abnormal connectivity patterns serving as key indicators supported by spectral analysis and deep learning classification. However, EEG research on EFL learners, particularly younger students, remains limited, including the lack of detailed brain topography mapping and the scarcity of studies conducted in authentic classroom contexts.

Third, EEG-based interventions—including neurofeedback, sleep management, meditation, aromatherapy, and vagus nerve stimulation, have demonstrated potential to reduce anxiety by modulating alpha, theta, and beta activity (Bremner et al., 2020; Chellappa & Aeschbach, 2022).. Nevertheless, most evidence focuses on general or clinical anxiety rather than learning-specific anxiety. Few studies directly evaluate EEG as both a diagnostic and intervention tool to enhance learning performance and regulate academic emotions in formal educational settings. EEG-based intervention demonstrate efficacy in reducing anxiety through the modulation of alpha, theta, and beta oscillatory activity. However, the current body of evidence is predominantly derived from general or clinical populations, with limited empirical studies investigating

Overall, while EEG provides robust evidence for identifying and modulating anxiety-related neural activity, further research is needed to develop targeted, classroom-based interventions that address learning-specific anxiety, particularly among EFL learners and younger populations. These findings imply that future research should prioritize the integration of EEG-based approaches into authentic classroom environments and develop neuroscience-informed teaching strategies that

address learners' emotional and cognitive needs, particularly in English language learning contexts.

## Conclusion

This systematic literature review demonstrates that electroencephalography (EEG) can effectively detect learning-related anxiety through increased beta activity and decreased alpha and theta activity, particularly in the prefrontal cortex, which reflects cognitive stress and emotional dysregulation. Additional activation is observed in the frontal, parietal, temporal, and limbic regions. Non-pharmacological interventions, such as neurofeedback, also show potential in reducing anxiety by modulating brainwave patterns, highlighting EEG's value not only as a diagnostic tool but also as a foundation for intervention. These findings underscore the importance of integrating neurophysiological data into educational practice to support neuroscience-informed instructional design. However, most existing studies remain laboratory-based and rarely incorporate affective variables such as motivation and self-confidence or involve younger learners in authentic classroom contexts. Therefore, future research should adopt longitudinal, classroom-based approaches, particularly in foreign language learning—to further develop EEG as both a mapping and intervention tool for managing learning anxiety and enhancing academic performance.

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