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EFFECTS OF NEUROFEEDBACK ON COGNITIVE PERFORMANCE IN OLDER ADULTS: A SYSTEMATIC REVIEW

EFEITOS DO NEUROFEEDBACK NO DESEMPENHO COGNITIVO DE IDOSOS: UMA REVISÃO SISTEMÁTICA

EFECTOS DEL NEUROFEEDBACK EN EL RENDIMIENTO COGNITIVO EN ADULTOS MAYORES: UNA REVISIÓN SISTEMÁTICA

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Abstract

With the global population aging, the demand for interventions capable of combating cognitive decline is increasing. Neurofeedback (NFB), a non-invasive brain training technique, has shown potential to improve cognitive functions in older adults. This systematic review aimed to evaluate the effects of NFB on cognition in older people. The study followed PRISMA guidelines and used the PICO strategy to structure the research question. Searches were conducted in the PubMed, Scopus, BVS, and Web of Science databases, covering articles published between 2020 and 2025. Risk of bias was assessed using the Cochrane RoB 2 and ROBINS-I V2 tools. Of the 249 studies initially identified, 8 met the inclusion criteria. Four studies included healthy individuals, and the other 4 included participants with clinical conditions, such as... In healthy older adults, positive effects were identified for fNIRS-based NFB, whereas interventions focused on gamma synchronization via brain-computer interface did not demonstrate consistent cognitive benefits. In participants with cognitive impairment, findings varied according to the protocol and the clinical profile of the sample. In conclusion, NFB shows promising potential as an intervention for older adults, but methodological diversity and limitations in some studies prevent definitive conclusions.
Keywords: Neurofeedback; EEG; Elderly; Cognition; Cognitive training.

Resumo

Com o envelhecimento da população global, cresce a demanda por intervenções capazes de combater o declínio cognitivo. O neurofeedback (NFB), uma técnica não invasiva de treinamento cerebral, tem demonstrado potencial para melhorar funções cognitivas em idosos. Esta revisão sistemática teve como objetivo avaliar os efeitos do NFB na cognição de pessoas idosas. O estudo seguiu as diretrizes PRISMA e utilizou a estratégia PICO para estruturar a pergunta de pesquisa. As buscas foram realizadas nas bases PubMed, Scopus, BVS e Web of Science, contemplando artigos publicados entre 2020 e 2025. O risco de viés foi avaliado por meio das ferramentas Cochrane RoB 2 e ROBINS-I V2. Dos 249 estudos inicialmente identificados,8 atenderam aos critérios de inclusão. 4 estudos incluíram

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indivíduos saudáveis, e os outros 4 incluíram participantes com condições clínicas, como. Nos idosos saudáveis, foram identificados efeitos positivos do NFB baseado em fNIRS, enquanto intervenções com foco na sincronização gama via interface cérebro-computador não demonstraram benefícios cognitivos consistentes. Em participantes com comprometimento cognitivo, os achados variaram conforme o protocolo e o perfil clínico da amostra. Em conclusão, o NFB apresenta potencial promissor como intervenção para idosos, mas a diversidade metodológica e as limitações de alguns estudos impedem conclusões definitivas.
Palavras-chave: Neurofeedback; EEG; Idosos; Cognição; Treinamento cognitivo.

Resumen

Con el envejecimiento de la población mundial, aumenta la demanda de intervenciones capaces de combatir el deterioro cognitivo. El neurofeedback (NFB), una técnica no invasiva de entrenamiento cerebral, ha mostrado potencial para mejorar las funciones cognitivas en personas mayores. Esta revisión sistemática tuvo como objetivo evaluar los efectos del NFB sobre la cognición en adultos mayores. El estudio siguió las directrices PRISMA y utilizó la estrategia PICO para estructurar la pregunta de investigación. Las búsquedas se realizaron en las bases de datos PubMed, Scopus, BVS y Web of Science, abarcando artículos publicados entre 2020 y 2025. El riesgo de sesgo se evaluó mediante las herramientas Cochrane RoB 2 y ROBINS-I V2. De los 249 estudios identificados inicialmente, 8 cumplieron con los criterios de inclusión. Cuatro estudios incluyeron individuos sanos y los otros 4 incluyeron participantes con condiciones clínicas, como... En adultos mayores sanos, se identificaron efectos positivos del NFB basado en fNIRS, mientras que las intervenciones centradas en la sincronización gamma mediante interfaz cerebro-computadora no mostraron beneficios cognitivos consistentes. En los participantes con deterioro cognitivo, los hallazgos variaron según el protocolo y el perfil clínico de la muestra. En conclusión, el NFB presenta un potencial prometedor como intervención para personas mayores, pero la diversidad metodológica y las limitaciones de algunos estudios impiden llegar a conclusiones definitivas.
Palabras clave: Neurofeedback; EEG; Adultos mayores; Cognición; Entrenamiento cognitivo.

1. Introduction

In 2019, approximately 9% of the world's population was aged 65 years or older[42]. It is estimated that the proportion of older adults worldwide will reach nearly 12% by 2030 and 16% by 2050[42]. In this context, population aging has become a global trend, resulting in a growing demand for information, healthcare services, and health education tailored to the needs of the older population[38]. Following the guidelines of American societies (American College of Cardiology/American Heart Association; American College of Cardiology Foundation/American Heart Association), an "older adult" is defined as an individual aged 65 years or older[6,34]. Although there is no universal definition for this term and it is influenced by contextual factors such as socioeconomic conditions and life expectancy, this criterion was adopted to standardize the population to be studied and to ensure greater methodological consistency[43].

Aging is often accompanied by cognitive decline, manifested by changes in

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memory, attention, and executive functions[20]. Although these changes may be part of the normal aging process, more pronounced deficits can lead to conditions such as Mild Cognitive Impairment (MCI) and increase the risk of developing neurodegenerative diseases, such as Alzheimer's disease[20]. In light of this, as the global population ages, it becomes increasingly necessary to develop interventions capable of improving or maintaining cognitive functions in older adults[22].

In this regard, neurofeedback (NFB), a non-invasive form of brain training based on providing real-time feedback of neural activity, has emerged as a promising tool for cognitive enhancement[30]. By modulating specific brain rhythms, typically through electroencephalography (EEG), NFB aims to strengthen cognitive functions such as working memory and episodic memory[30].

Despite the potential of NFB as a cognitive enhancement strategy, the existing literature presents methodological limitations, such as the lack of adequate controls and variability in intervention protocols[23]. Given these limitations, a systematic review becomes essential to compile the most robust evidence on the effects of NFB on cognitive performance in older adults and to assess the applicability of this tool in clinical practice. Furthermore, although individual studies show promising results, a synthesis of findings is necessary to confirm the efficacy of NFB and to highlight important associated factors, such as electroencephalographic targets and the cognitive domains assessed.

The present systematic review aimed to investigate the effects of NFB on cognitive performance in older adults. It seeks to evaluate the efficacy of NFB in improving different cognitive domains in this population, such as memory and attention, including both healthy participants and those with clinical conditions.

2. Methodology

To conduct the present study, the recommendations of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) were used as a reference. This instrument provides a standardized approach for reporting systematic reviews and meta-analyses[29]. The study consists of a systematic literature review. The PICO method was used to develop the eligibility criteria as follows: P (population): older

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adults; I (intervention): use of neurofeedback with the aim of assessing and improving cognitive performance; C (comparison): control group; O (outcome): effects on cognitive performance.

Randomized clinical trials (RCTs) and quasi-experimental studies that investigated the use of NFB in older adults and reported the effects of this intervention on cognition were included. The following were excluded: studies involving populations other than older adults, studies that did not present the NFB protocols used, and those that did not assess cognitive performance. Studies published between 2020 and 2025 were selected in order to include more recent evidence in the scientific literature. In addition, studies with mixed groups (adults and older adults) were included to avoid an excessive reduction in the number of eligible studies, since the scientific production focused exclusively on the older adult population (individuals aged 65 years or older) is still limited. However, the possible heterogeneity introduced by this decision is acknowledged and was considered in the interpretation of the results.

The articles were selected independently by two researchers. Discrepancies were resolved by a third evaluator, responsible for reading the full text of the article and assessing its eligibility to be included in the sample. Article selection took place from April 8 to 11, 2026. Studies published between 2020 and 2025, in English, were selected from the PubMed, Scopus, Virtual Health Library (VHL), and Web of Science databases. The guiding research question for the study was: “What is the effect of using NFB on the cognitive performance of older adults?”

In view of this, the keywords contained in the research question were identified and converted into the most appropriate descriptors indexed in the Medical Subject Headings (MeSH) database. Subsequently, these terms were combined using the Boolean operators “AND” and “OR”, resulting in the final search strategy: ((Neurofeedback) OR (Biofeedback) OR AND (Cognition) AND ((Aged) OR (Elderly)) AND ((Electroencephalography) OR (EEG) OR (Magnetic Resonance Imaging) OR (fMRI)) OR (fNIRS).

All stages of article selection were guided by previously established eligibility criteria. Initially, studies retrieved from the databases (PubMed, Web of Science, VHL, and Scopus) were screened using the Rayyan software[26]. The first screening stage

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consisted of reading the titles and abstracts of the studies, selecting those to be read in full in the second stage. In the second stage, potentially relevant studies were analyzed in full, and only those that met the inclusion criteria were retained.

For quasi-experimental studies, version 2 of the Cochrane Risk of Bias in Non-randomized Studies of Interventions (ROBINS-I V2) tool was used to assess the risk of bias[37,39]. The tool considers six domains: bias due to confounding; bias in the classification of interventions; bias in the selection of participants into the study or into the analysis; bias due to missing data; bias in the measurement of outcomes; and bias in the selection of reported results. Each outcome was classified as having low, moderate, serious, or critical risk of bias, based on algorithms derived from responses to signaling questions, and could be adjusted according to the reviewers' judgment. In general, an outcome is classified as low risk of bias when all domains are at low risk; it is classified as moderate risk when at least one domain presents moderate risk, with no domains at serious or critical risk. Serious risk is assigned when there is at least one domain with serious risk, in the absence of critical risk, or when multiple domains with moderate risk indicate important limitations. Critical risk is assigned when there is at least one domain with critical risk or when multiple domains with serious risk substantially compromise the validity of the outcome. The assessment was conducted independently by two reviewers, with consensus reached through discussion.

For RCTs, the risk of bias (RoB) assessment was conducted using the Cochrane RoB 2 tool[40], following the Cochrane Handbook for Systematic Reviews of Interventions[3]. The tool comprises five domains: bias arising from the randomization process; bias due to deviations from intended interventions; bias due to missing outcome data; bias in the measurement of outcomes; and bias in the selection of reported results. Each domain was classified as "Low risk," "Some concerns," or "High risk." Studies were considered "Low risk" when all domains were rated as low risk. They were classified as "Some concerns" when at least one domain raised concerns, with no domain rated as high risk. Studies with at least one domain classified as "High risk" were categorized as "High risk." Furthermore, when multiple domains presented concerns that substantially reduced confidence in the results, the overall classification was also considered "High risk."

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Two authors independently assessed the risk of bias of each study, with disagreements resolved through discussion. Only additional documents already available, such as study protocols and/or statistical analysis plans, were reviewed to support the assessment. Relevant variables were extracted, considering factors such as age and sex of the sample, sample size, type and protocol of NFB used, and cognitive assessment instruments employed. The results of the systematic review were interpreted by the authors, leading to discussions and conclusions regarding the findings. The systematic review used exclusively secondary data; that is, the research did not collect data directly from human or animal participants. It is worth noting that, despite the detailed methodological approach, the absence of a registered systematic review protocol should be highlighted as a methodological limitation.

3. Results

Study Selection

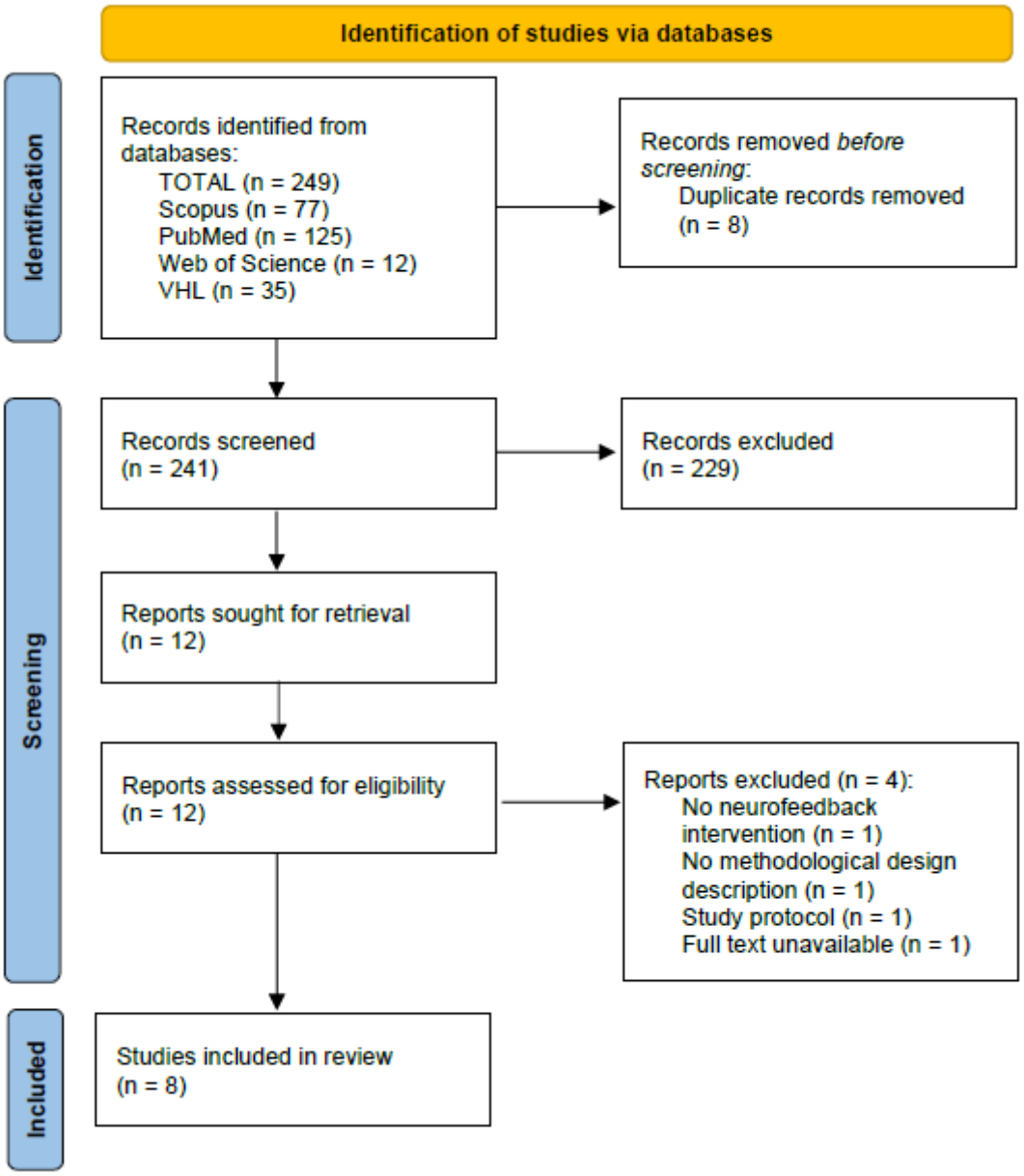
A total of 249 records were identified across the databases PubMed (n = 125), Scopus (n = 77), Web of Science (n = 12), and VHL (n = 35). After the removal of 8 duplicates, 241 records were screened by title and abstract, of which 229 were excluded for not meeting the inclusion criteria. A total of 12 articles remained and were assessed for eligibility through full-text review. Of these, four articles were excluded for the following reasons: absence of a NFB intervention[24], lack of description of the methodological design[1], classification as a study protocol[17], and unavailability of the full text[31].

Finally, eight studies[2,5,10,14,15,19,27,41] met the inclusion criteria and were considered eligible for the review. Figure 1 presents the article selection process.

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Figure 1 - Selection of Studies.



Source: Authors, 2026.

Characteristics of the Studies

The included studies varied in terms of study design, geographical location, participant characteristics, and sample sizes (Table 1).

Regarding the methodological design of the studies, a balanced distribution was observed in the analyzed sample, with four studies characterized as RCTs[5,10,14,27] and

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four as quasi-experimental studies[2,15,19,41] (Tables 2 and 3).

Geographically, the included studies covered different regions of the world, with investigations conducted across three continents: Europe, North America, and Asia.

In Europe, the studies were carried out in Germany[10] and France[5,14,27]. North America was represented by the United States[2], while Asia contributed studies from China[41], South Korea[19], and Thailand[15].

A predominance of publications originating from France was observed, accounting for three of the eight articles included in the sample[5,14,27]. The remaining countries each contributed one study.

Table 1. Characteristics of the Participants.

N	Author, year	Sample size	Sex F (M)	Age	Participants
1	Acevedo; Dattatri; Marhenke, 2023[2]	77	58 (19)	54 - 84 years MA: 66.2 NFTG: 68.38 ± 6.96 CG: 63.03 ± 5.8	Healthy adults and older adults
2	Andrade et al., 2024[5]	31	21 (10)	> 55 years MA: 72 NFTG: 71 ± 7.6 CG: 73 ± 5.5	Healthy adults and older adults
3	Fink et al., 2023[10]	42	28 (14)	31 - 73 years NFTG: 52.95 ± 10.5 CG: 50.33 ± 8.7	Adults and older adults diagnosed with malignant tumors
4	Houmani et al., 2025[14]	31	21 (10)	>55 years MA: 72 NFTG: 71 ± 7.6 CG: 73 ± 5.5	Healthy adults and older adults

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5	Israsena et al., 2021[15]	43	Not reported.	MA: 69.66 ± 7.5	Healthy adults and older adults
6	Kim; Weon; Son, 2024[19]	59	25 (34)	≥ 65 anos NFTG: 77.54 ± 6.37 CG: 76.35 ± 6.09	Older adults with presbycusis
7	Paban et al., 2024[27]	36	27 (9)	Age ranged from 60 to 81 years. Ind-NFB: 68.64 ± 8.67 St-NFB: 72.46 ± 6.25	Adults and older adults with subjective cognitive decline
8	Su et al., 2025[41]	28	12 (16)	Age ranged from 60 to 70 years. 65.12 ± 4.31	Adults and older adults with amnestic mild cognitive impairment

Source: Authors, 2026.

Legend: F: female; M: male; MA: mean age; NFTG: neurofeedback training group; CG: control group; Ind-NFB: individualized neurofeedback treatment group; St-NFB: standardized neurofeedback treatment group.

A total of 347 participants were included in the review, with individual sample sizes ranging from 28[41] to 77[2] participants. A predominance of female participants was observed, with the exception of two studies[19,41], which had a majority of male participants, and one study[15] that did not report sex distribution. Regarding age, participants had mean ages predominantly above 65 years, although the study by Fink et al. (2023)[10] stood out for including younger adults, resulting in the lowest mean ages.

Interventions in Healthy Individuals

Four studies investigated NFB in healthy individuals[2,5,14,15]. Of these, two were RCTs[5,14]. It is important to note that the study by Houmani et al. (2025)[14] continued the work of Andrade et al. (2024)[5], deepening the analysis to investigate the individual

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heterogeneity of the aggregated results. In addition, the two remaining studies had a quasi-experimental design[2,15] and investigated the use of NFB with functional near-infrared spectroscopy (fNIRS)[2] and individual alpha peak training[15] (Table 2).

The studies analyzed show heterogeneous and, in general, limited results regarding the effects of NFB in healthy individuals, varying according to the type of NFB used, the cognitive domains and cognitive tests employed, as well as the risk of bias assessment of the studies (Table 2).

In the trial that investigated the effects of NFB with a brain-computer interface (BCI) through peak alpha wave training, theta/beta ratio, and, primarily, gamma-band synchronization, no consistent cognitive improvements were observed[5] in the following instruments: the Mini-Mental State Examination[11], the Free and Cued Selective Reminding Test[13], the Trail-Making Test A and B[36], the Digit Span Test[5], the Frontal Assessment Battery[9], and the 15-item version of the McNair Frequency of Forgetting Questionnaire[25]. Despite this finding, it was shown that healthy older adults were able to significantly modulate gamma-band synchronization after the intervention, distinguishing the real-training group from the sham group with 71% accuracy, which was a group-level result obtained through supervised learning[5] (Table 2).

Continuing directly from that work, the study by Houmani et al. (2025)[14] employed a two-step unsupervised approach (agglomerative hierarchical clustering by individual followed by population spectral bi-clustering) and revealed that the neuromodulatory effect was not uniform: only a specific subgroup of participants in the NFB group (five of the seventeen) exhibited a robust increase in gamma synchrony, accompanied by a consolidation that extended across the entire frequency spectrum[14]. In light of this, Houmani et al. (2025)[14] demonstrated a possible neural signature of effective brain self-regulation; that is, the previous group-level findings of Andrade et al. (2024)[5] coexist with highly variable response patterns among participants (Table 2).

On the other hand, two quasi-experimental studies indicate specific positive effects that depend on individual characteristics and on the cognitive domain assessed. Acevedo; Novia Dattatri; Marhenke (2023)[2] demonstrated that the effects of NFB with fNIRS varied according to the level of sensory processing sensitivity (SPS), measured

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by the 16-item Highly Sensitive Person (HSP) Scale[33], with significant improvement in visual memory among individuals with high SPS and gains in sustained attention among those with low SPS, with no effects in the remaining domains. Cognitive assessment was conducted using the Verbal Memory Test, the Visual Memory Test, the Shifting Attention Test, the Four-Part Continuous Performance Test (assessing working memory and sustained attention)[2], and Symbol Digit Coding (assessing processing speed)[2] (Table 2).

Israsena et al. (2021)[15], using NFB with individualized alpha peak training, identified significant improvements in visual memory, sustained attention, and visuospatial working memory assessed by the Cambridge Neuropsychological Test Automated Battery (CANTAB)[15], as well as corresponding electrophysiological changes, such as increased occipital alpha activity[15]. In summary, Israsena et al. (2021)[15] and Acevedo; Novia Dattatri; Marhenke (2023)[2] suggest that NFB may promote specific cognitive gains in healthy individuals, but not in a generalized manner, with its efficacy being influenced by individual factors such as SPS and by the cognitive domain investigated[2,15] (Table 2).

It is worth noting that the risk of bias assessment showed that the studies by Andrade et al. (2024)[5] and Houmani et al. (2025)[14] presented “some concerns” according to the RoB 2 tool. The study by Acevedo; Novia Dattatri; Marhenke (2023)[2] presented moderate risk according to the ROBINS-I V2 assessment. The study by Israsena (2021)[15] was classified as having critical risk of bias, mainly related to critical risk due to confounding factors such as age, education, baseline cognition, or other prognostic factors, which were not adjusted for. Therefore, the validity of the findings should be interpreted with caution, especially in the case of improvements in visual memory, sustained attention, and visuospatial working memory with individualized alpha peak NFB (15) (Table 4) (Table 5).

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Table 2. Characterization of the interventions in studies involving healthy individuals.

Author	Design	Type of NFB	Protocol	Cognitive Assessment	Outcomes
Acevedo; Novia Dattatri; Marhenke, 2023[2]	Quasi-experimental	fNIRS	10–15 minutes per day, 5–7 days per week, for 4 weeks.	VBM, VSM, SDC, SAT e 4CPT	High SPS: ↑ visual memory; ↑ global memory (p = 0.06) Low SPS: ↑ sustained attention.
Andrade et al., 2024[5]	RCT	BCI (PAF, TBR e gamma-band synchronization)	20 sessions of 30 minutes over 3 months.	MMSE, FCSRT, TMT A and B, Digit span test, FAB e MFFQ	↑ Gamma synchronization; no cognitive improvement observed.
Houmani et al., 2025[14]	RCT	BCI (PAF, TBR e gamma-band synchronization)	20 sessions of 30 minutes over 3 months.	MMSE, FCSRT, TMT A and B, Digit span test, FAB e MFFQ	↑ gamma; five individuals had global increase (all bands); no cognitive improvement.
Israsena et al., 2021[15]	Quasi-experimental	Alpha (IAP 7,5–12,5 Hz)	20 sessions (2x/week; 30 minutes each).	CANTAB	↑ visual memory, visuospatial working memory, and attention.

Source: Authors, 2026.

Legend: NFB: neurofeedback; RCT: randomized clinical trial; fNIRS: functional near-infrared spectroscopy; VBM: verbal memory test; VSM: visual memory test; SDC: symbol-digit coding test; SAT: shifting attention test; 4CPT: four-part continuous performance test; SPS: sensory processing sensitivity; BCI: brain-computer interface; PAF: peak alpha frequency; TBR: theta/beta ratio; MMSE: mini-mental state examination; FCSRT: free and cued selective reminding test; TMT-A: trail making test a; TMT-B: trail making test b; FAB: frontal assessment battery; MFFQ: mcnair frequency of forgetting questionnaire; IAP: individual alpha peak; CANTAB: cambridge neuropsychological test automated battery.

Four studies investigated the use of NFB in clinical populations[10,19,27,41]. Among them, two were conducted in individuals with cognitive impairment[27,41], one included patients diagnosed with malignant tumors[10], and another assessed individuals with presbycusis who used hearing aids[19] (Table 3).

Regarding the clinical subgroup of individuals with cognitive impairment, the two studies yielded divergent results, depending on the methodological design, the NFB

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protocols used, the cognitive assessment instruments employed, and the classification of cognitive impairment[27,41] (Table 3).

The study by Paban et al. (2024)[27], an RCT, evaluated the effects of individualized NFB (12 and 18 Hz—beta, although other frequencies were also used according to the needs of each profile) and standardized NFB (peak alpha frequency ± 1 Hz) in people with subjective cognitive decline, a classification determined on the basis of baseline scores on the Cognitive Change Index (self-report) (CCI-S)[28,35]. When the pre- and post-training periods were compared, regardless of protocol, no statistically significant differences were observed in the cognitive-behavioral measures Cognitive Change Index (self-report)[35] and Metacognitions Questionnaire[8]. Nevertheless, it is important to note that an important limitation may have been the choice of assessment instruments: because the study relied solely on self-reports, subtler or more objective effects may have gone undetected[27]. In addition, individuals with subjective cognitive decline may not show detectable changes on neuropsychological tests, which may make it harder for cognitive tests to identify less sensitive changes[27] (Table 3).

Also within the clinical subgroup of individuals with cognitive impairment, the quasi-experimental study by Su et al. (2025)[41] used the “Mind-Force Ant” game, a multimodal NFB training (focus/relaxation) in individuals with amnestic MCI[41]. After the intervention, of the 28 patients assessed, 26 showed a significant improvement in Montreal Cognitive Assessment (MoCA) scores[41]. However, the authors themselves emphasized that the durability of the cognitive improvements still needs to be investigated with longer follow-up periods. Alongside this cognitive improvement, a significant increase in connectivity strength in the delta frequency band was observed after the intervention. In contrast, an overall reduction in connectivity was observed in the theta, alpha, and beta bands[41] (Table 3).

Given the heterogeneity observed across the studies[27,41], it is difficult to generalize the findings and propose a conclusive synthesis. In other words, the variability in methodological design, the NFB protocols used, the cognitive assessment instruments employed, and the classification of cognitive impairment limits the comparability of the results (Table 3).

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Regarding methodological quality, the study by Paban et al. (2024)[27] showed a high risk of bias (RoB 2), mainly due to deviations from the intended interventions. This was largely because of the per-protocol analysis, which excluded a considerable number of participants after randomization, especially the "non-responders," who were more frequent in the individualized NFB group, potentially influencing the results even though the study found no significant differences between groups[27]. The study by Su et al. (2025)[41], on the other hand, was classified as having serious risk of bias (ROBINS-I), mainly because of confounding factors and the way outcomes were measured. As this was a single-arm pre-post study without a comparison group, it is difficult to state whether the positive effects observed were truly due to NFB or whether they may have been explained by other factors such as natural disease progression, placebo effects, or learning effects[41] (Tables 4 and 5).

Two other studies evaluated NFB in individuals with different clinical conditions: one included patients diagnosed with malignant tumors[10] and the other assessed individuals with presbycusis who used hearing aids[19]. The RCT by Fink et al. (2023)[10] used NFB training with alpha enhancement (9–13 Hz) and theta/beta ratio reduction (>20 Hz) in patients diagnosed with malignant tumors. After the intervention, no significant effects on participants' cognition were found. The primary outcome was the subjective perception of cognitive impairment (assessed using the Perceived Cognitive Impairments subscale of the FACT-Cog questionnaire)[4,7], and no significant improvement in cognitive complaints was observed over time. The quasi-experimental study by Kim, Weon, and Son (2024)[19], in turn, tested NFB with alpha-wave enhancement training (8–12 Hz) in individuals with presbycusis who used hearing aids and reported improvement in global cognitive function and short-term memory/attention, as assessed by the Mini-Mental State Examination[32] and the Digit Span Test[18] in the forward condition (Table 3).

Overall, both the study by Fink et al. (2023)[10] and that by Kim, Weon, and Son (2024)[19] used alpha-based protocols; however, Fink et al. (2023)[10] also included training targeting the theta/beta ratio and assessed a population different from that of Kim, Weon, and Son (2024)[19]. The results were divergent, since Kim, Weon, and Son (2024)[19] observed positive effects, whereas Fink et al. (2023)[10] did not identify any

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improvement in cognitive performance. It is worth noting that Fink et al. (2023)[10] conducted an RCT, whereas Kim, Weon, and Son (2024)[19] carried out a quasi-experimental study (Table 3). Regarding risk of bias, the study by Fink et al. (2023)[10] was classified as having "some concerns" in RoB 2, while the study by Kim, Weon, and Son (2024)[19] showed moderate risk according to ROBINS-I (Tables 4 and 5).

Table 3. Interventions of studies involving individuals with clinical conditions.

Author	Design	Type of NFB	Protocol	Cognitive Assessment	Outcomes
Fink et al., 2023[10]	RCT	Alpha enhancement (9–13 Hz) and theta/beta ratio reduction (>20 Hz)	6–10 sessions, 2×/week; 35–40 minutes.	FACT-Cog	No significant effects on cognitive performance.
Kim; Weon; Son, 2024[19]	Quasi-experimental	Alpha-wave enhancement (8–12 Hz)	16 sessions (2×/week; 40 minutes)	MMSE and Digit Span test	↑ MMSE scores; ↑ Digit Span in the forward condition.
Paban et al., 2024[27]	RCT	Ind-NFB: 12 and 18 Hz (beta), but other frequencies were also used according to the needs of each profile. St-NFB: PAF ± 1 Hz	Variable number of sessions, up to 3 consecutive successful sessions, 2×/week; 36–40 minutes.	Cognitive Change Index (self-report) and Metacognitions Questionnaire	No significant improvements were found in cognitive assessment tests in either protocol.
Su et al., 2025[41]	Quasi-experimental	Multimodal (focus/relaxation)	2 cycles of 5 days, 2 sessions per day, 3 minutes each session, with a 1-hour interval between sessions	MoCA	92.9% of participants showed a significant increase in MoCA scores.

Source: Authors, 2026.

Legend: NFB: neurofeedback; RCT: randomized clinical trial; FACT-Cog: functional assessment of cancer therapy–cognitive function; MMSE: mini-mental state examination; Ind-NFB: individualized neurofeedback; St-NFB: standardized neurofeedback; PAF: peak alpha frequency; MoCA: montreal cognitive assessment.

The risk-of-bias analysis used the RoB 2 tool (Table 4) for RCTs and the ROBINS-I V2 tool for quasi-experimental studies (Table 5).

Table 4. Risk-of-bias assessment (RoB 2) of randomized clinical trials.

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Author, year	D1	D2	D3	D4	D5	Overall
Andrade et al., 2024[5]	Low	Some concerns	Some concerns	Low	Some concerns	Some concerns
Fink et al., 2023[10]	Low	Low	Low	Some concerns	Low	Some concerns
Houmani et al., 2025[14]	Low	Some concerns	Low	Low	Some concerns	Some concerns
Paban et al., 2024[27]	Some concerns	High	Low	Low	Some concerns	High

Source: Authors, 2026.
Legend: D1: bias arising from the randomization process; D2: bias due to deviations from intended interventions; D3: bias due to missing outcome data; D4: bias in measurement of the outcome; D5: bias in selection of the reported result**.**

Table 5. ROBINS-I V2 assessment of quasi-experimental studies.

Author, year	D1	D2	D3	D4	D5	D6	Overall
Acevedo; Novia Dattatri; Marhenke, 2023[2]	Moderate	Low	Moderate	Low	Moderate	Moderate	Moderate
Israsena et al., 2021[15]	Critical	Low	Moderate	Moderate	Moderate	Moderate	Critical
Kim; Weon; Son, 2024[19]	Moderate	Low	Low	Low	Moderate	Moderate	Moderate
Su et al., 2025[41]	Serious	Low	Moderate	Low	Serious	Moderate	Serious

Source: Authors, 2026.
Legend: D1: bias due to confounding; D2: bias in the classification of interventions; D3: bias in the selection of participants into the study or in the analysis; D4: bias due to missing data; D5: bias in measurement of outcomes; D6: bias in selection of the reported result.

4. Discussion

This systematic review evaluated the available evidence on the effects of NFB in older adults, including both RCTs and quasi-experimental studies. Considerable heterogeneity was observed among the included studies, especially with regard to the types of NFB employed, intervention protocols, population characteristics, and clinical conditions when present. This methodological variability makes direct comparison

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across findings difficult and limits the generalizability of the results. In this sense, the findings reinforce the need for greater standardization in future study designs, especially regarding protocol definition, inclusion criteria, and outcome measures.

Healthy older adults

Overall, the findings indicated positive effects of fNIRS-based NFB[2] and individual alpha peak-based NFB in healthy older adults[15], whereas interventions using BCI-based NFB focused on gamma synchronization did not demonstrate significant benefits[5,14]. However, it is important to note that the study investigating individual alpha peak NFB showed a critical risk of bias[15], mainly due to the lack of adequate control for potential confounding factors such as age, education, and baseline cognition. In the literature, the use of fNIRS-based NFB as cognitive training in healthy older adults was also evaluated by Acevedo et al. (2022)[1], with results suggesting that this intervention is effective for improving composite memory, verbal memory, processing speed, and executive function when compared with an active control group (Tetris)[1].

In Acevedo; Novia Dattatri; Marhenke (2023)[2], included in this review, the same fNIRS NFB program was reanalyzed to determine whether the SPS personality trait modulates these gains, and it was found that individuals with high sensitivity enhanced the effects on composite memory and visual memory, whereas individuals with low SPS showed improvements in sustained attention[2].

The null findings (absence of cognitive improvement) regarding the use of BCI-based NFB reported by Andrade et al. (2024)[5] and Houmani et al. (2025)[14] differ from those previously reported in the literature, particularly in the quasi-experimental study by Gomez-Pilar et al. (2016)[12], who found significant cognitive improvements after the intervention. This discrepancy may be due to differences in the sensorimotor rhythms used (alpha and beta, centered at 12, 18, and 21 Hz[12], versus individual peak alpha frequency, gamma synchronization at 35–45 Hz, and theta/beta ratio[5]).

It is worth emphasizing, however, that the quasi-experimental study by Gomez-Pilar et al. (2016)[12] suggests that an active BCI focused on sensorimotor rhythms may induce cognitive gains even with few sessions, but the study lacks the rigor of a placebo control. By contrast, the RCT by Andrade et al. (2024)[5], which is methodologically more

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robust, shows that older adults can specifically modulate gamma synchronization via pure NFB, but that this does not translate into cognitive improvement when participants already have high baseline performance. To reconcile these findings, studies combining double-blind rigor with active tasks would be needed, investigating different EEG biomarkers and including samples with varying baseline levels of cognition.

Older adults with cognitive impairment

Regarding the two included studies that involved older adults with cognitive impairment[27,41], there were differences in the type of cognitive impairment in the populations of the two articles, in the methodological design, and in the types of NFB used, making it impossible to draw an adequate synthesis based on the findings.

Compared with previously published studies, the findings of the present review indicate that the effects of alpha-wave NFB on cognition are inconsistent. The study by Lavy et al. (2021)[21], which used upper alpha training in individuals with MCI, demonstrated improvements in participants' memory. In contrast, Paban et al. (2024)[27], although also using frequencies in the alpha range, did not observe cognitive improvement in individuals with subjective cognitive decline. One possible explanation for this discrepancy is the difference between the populations studied, especially in the baseline level of cognitive impairment.

Similarly, the study by Jirayucharoensak et al. (2019)[16], conducted with amnestic participants, used an alpha and beta protocol and found improvements in the MoCA and CANTAB[16], while the study by Su et al. (2025)[41], with an amnestic MCI population, employed a multimodal intervention with focus and relaxation training through gamification and also showed cognitive improvement on the MoCA, despite the methodological differences between the protocols. Thus, the cognitive improvement assessed by the MoCA in both studies may indicate potential for the use of NFB across different protocols, specifically in the older population with amnestic MCI[16].

Limitations

This study had some limitations, including the absence of a registered

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systematic review protocol. In addition, another important limitation of this review concerns the inclusion of samples with mixed age ranges. Although we adopted 65 years as the operational criterion for defining older adults, 5 of the 8 included studies recruited participants with minimum ages ranging from 54 to 60 years[2,5,14,27,41]. Nevertheless, it is worth noting that, in most of these studies, the mean ages were within the older-adult range, which may partially mitigate this bias. The inclusion of these studies was necessary to avoid an excessive reduction in the number of available pieces of evidence. The study that deviates most from this profile is Fink et al. (2023)[10], which included participants aged 31 to 73 years, with lower mean ages (NFB training group: 52.95 ± 10.5; control group: 50.33 ± 8.7), although it still included older adults in the sample. Considering possible differences in cognitive performance and response to NFB between adults and older adults, this limitation may reduce the accuracy of extrapolating the results to the older population, thereby compromising comparability across studies.

Overall, confidence in the body of evidence is limited. Regarding the limitations of the included studies and, consequently, the reported results, the risk-of-bias assessment revealed serious methodological issues in part of the empirical evidence base: Israsena et al. (2021)[15] was classified as having a critical risk of bias, and the article by Su et al. (2025)[41] as having a serious risk of bias. In Su et al. (2025)[41], the lack of confounding control and the high potential for confounding make it impossible to attribute causality to the intervention; in Israsena et al. (2021)[15], the absence of adjustment for baseline confounders and the within-group analysis prevent the causal effect from being isolated, while Paban et al. (2024)[27] showed a high risk of bias, due to the per-protocol analysis that excluded a large post-randomization group and selective reporting. Kim, Weon e Son (2024)[19], Acevedo; Novia Dattatri; Marhenke (2023)[2] and Fink et al. (2023)[10] had moderate risk of bias (“some concerns”), with limitations mainly related to statistical control of confounding and blinding, but without indications that these biases completely invalidated the findings.

5 CONCLUSIONS

The development of this study allowed for a comprehensive understanding of the

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different dimensions of NFB use in the cognition of older adults. In summary, this review highlights NFB as a promising tool for enhancing cognitive functions, particularly memory and attention, in older adults. Despite some encouraging results, the diversity of study designs, heterogeneity of participant characteristics, and methodological issues indicate the need for further research with more robust designs. Future studies should prioritize standardized protocols, larger and more diverse samples, and rigorous RCTs to confirm their reliability, applicability, and long-term benefits. Although some findings suggest potential for the therapeutic use of NFB in age-related cognitive decline, the evidence is not yet sufficiently robust to recommend its implementation as an established clinical option. Thus, rigorous future investigations are needed to consolidate its role in geriatric practice.

Conflict of Interest Statement

The authors declare no conflicts of interest.

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