

Intervention Methods for Working Memory: A Systematic Review

Métodos de Intervención Para la Memoria de Trabajo: Una Revisión Sistemática

Carlos Ramos-Galarza, Angela Vanegas

Abstract

Working memory refers to storing and manipulating information to achieve a specific goal or completing a task at a high cognitive level. This component is part of the executive functions and is essential for daily life. A quantitative systematic review aims to identify the intervention methods currently developed to rehabilitate and improve working memory. The articles were obtained from SCOPUS, ScienceDirect, PubMed, and Scielo databases. Initially, 550 articles were found, and after applying the inclusion and exclusion criteria, 65 articles were selected and included in the data extraction process and used for the descriptive statistical analysis. The main results found that computerized treatments prevailed in 41 studies, transcranial electrical stimulation in 16, and sport and cognitive stimulation in two, respectively. These findings will be analyzed to develop new proposals that can contribute to clinical practice and offer mental health professionals a selection of intervention methods helpful in carrying out intervention plans aimed at working memory deficits.

Keywords: Working memory, systematic review, executive functions, intervention, working memory training

Resumen

La memoria de trabajo se refiere al almacenamiento y la manipulación de la información para alcanzar un objetivo específico o completar una tarea a un alto nivel cognitivo. Este componente forma parte de las funciones ejecutivas y es esencial para la vida diaria. Una revisión sistemática cuantitativa pretende identificar los métodos de intervención desarrollados actualmente para rehabilitar y mejorar la memoria de trabajo. Los artículos se obtuvieron de las bases de datos SCOPUS, ScienceDirect, PubMed y Scielo. Inicialmente se encontraron 550 artículos y, tras aplicar los criterios de inclusión y exclusión, se seleccionaron 65 artículos que se incluyeron en el proceso de extracción de datos y se utilizaron para el análisis estadístico descriptivo. Los principales resultados hallaron que los tratamientos informatizados prevalecieron en 41 estudios, la estimulación eléctrica transcraneal en 16, y el deporte y la estimulación cognitiva en dos, respectivamente. Estos hallazgos se analizarán para desarrollar nuevas propuestas que puedan contribuir a la práctica clínica y ofrecer a los profesionales de la salud mental una selección de métodos de intervención útiles para llevar a cabo planes de intervención dirigidos a los déficits de la memoria de trabajo.

Palabras clave: Memoria de trabajo, revisión sistemática, funciones ejecutivas, intervención, entrenamiento de la memoria de trabajo

Rev. Ecuat. Neurol. Vol. 34, N° 3, 2025

Introduction

Executive functions are a set of higher cognitive abilities responsible for regulating mental abilities and directing, coordinating, and adapting behavior to achieve goals and perform complex tasks.¹ The central executive functions are inhibitory control, working memory (our focus in this study), cognitive flexibility, reasoning, planning, and problem-solving.^{2,3} In everyday life, executive functions are determinants for adequate performance in various situations, such as work, school, environmental adaptation,

social relationships, learning, and physical and psychological development.²

Working memory is an operating system of limited capacity that stores information temporarily and connects with long-term memory to retrieve, process, and manipulate previously stored data to perform high-level cognitive tasks.⁴ Baddeley and Hitch⁵ significantly contributed to the study of working memory, proposing a three-component model: the central executive, the visuospatial agenda, and the phonological loop. Later, Baddeley⁴ added

a fourth component called the episodic buffer, which episodically stores and integrates the visual and verbal codes of the other two systems and long-term memory. Working memory is crucial for language, comprehension, reasoning, learning, and decision-making.^{2,6}

Based on neuroimaging studies, it is known that the neuroanatomical and neurobiological substrate of working memory is in structures of the prefrontal cortex (central manager of working memory), in connection with cortical and subcortical areas.^{7,8} Specifically, the dorsolateral and medial prefrontal cortex are involved in visuospatial information, while the ventrolateral prefrontal cortex handles non-spatial information. The left temporoparietal region is crucial for phonological retention, and the right inferior parietal cortex, right premotor cortex, right inferior frontal cortex, and occipital cortex are involved in processing verbal, visual, and spatial information.⁸⁻¹⁰ On the other hand, it is known that the functioning of working memory is regulated by frontostriatal pathways, dopaminergic pathways, and the GABA system, which are involved in neural mechanisms that allow the maintenance and updating of information during the performance of complex cognitive tasks.¹¹

Working memory is an indispensable cognitive process crucial for functioning autonomously, achieving immediate and short-term goals, and effectively performing daily activities.^{9,12} Being an active information store that continuously updates and manipulates information, it is closely related to everyday tasks such as reading, writing, driving a car, learning a new language, learning new habits, performing mathematical operations, language comprehension, creativity, reasoning, and decision-making.^{9,13} It is one of the executive functions most involved in human learning, as several investigations have evidenced the direct correlation between working memory and academic performance.¹⁴⁻²⁰ In addition, it is involved in inhibiting automatic response and attentional switching, which increases processing efficiency in problem-solving.¹⁴

Currently, research shows a link between impairments in working memory and various mental disorders and pathologies. These impairments are particularly prevalent in neurodevelopmental disorders such as ADHD,^{21,22} intellectual disability,²³ and autism spectrum disorders.^{22,24} Working memory deficits are also observed in neurodegenerative disorders like Parkinson's and Alzheimer's disease^{21,25} and severe psychiatric disorders including schizophrenia,^{26,27} generalized anxiety, major depression,²⁸ panic disorder,²⁹ and bipolar disorder.^{30,31} Working memory performance has also been investigated in individuals who have experienced a stroke,³² a brain injury,³³ COVID-19 infection,³⁴ as well as in aging, medication side effects,²¹ cannabis use,³⁵ stress,³⁶ Duchenne muscle dystrophy,³⁷ multiple sclerosis,³⁸ obesity,³⁹ and sleep deprivation.⁴⁰

Working memory training is an area that continues to be studied. It is known that neuroplasticity allows this executive function to be modified, improved, and enhanced. This has opened doors for applying stimulation in populations with different mental pathologies and individuals with normal cognitive development.⁷ Working memory training is performed using various methods, such as computerized programs (e.g., Cogmed),^{41,42} mnemonic strategies,⁴² mindfulness training,⁴³ transcranial electrical stimulation,⁴⁴ and working memory tasks (dual n-back tasks, forward and backward simple span tasks, running memory tasks, selective updating tasks).⁴⁵

Establishing an intervention plan for working memory impairment in clinical practice can be challenging due to the lack of a standardized approach to working memory training and rehabilitation methods. Therefore, this exploratory systematic review will investigate current tools and techniques involved in working memory intervention.

Method

The scope of the present study is based on a quantitative systematic review of the published scientific literature on clinical intervention and treatment of working memory. The PRISMA method was used for its development (see Figure 1), following the guidelines established by Arksey and O'Malley⁴⁶ and Levac et al.⁴⁷ The stages of the study development are detailed below.

The study's first phase involved determining the research question and conducting the initial data search. We combined the keywords "working memory," "treatment," "intervention," "therapy," "training," and "neuropsychology" in SCOPUS, Science Direct, PubMed, and Scielo databases, limiting the results to publications from the past five years (2019-2024). The most successful search combination across the databases was ("working memory") AND (training) OR (stimulation) AND (intervention). A reviewer provided feedback on the ideas presented in this research and oversaw the research process, which included reviewing titles, abstracts, types of interventions or training, and assessment instruments.

In the second stage, data collection yielded 160 documents in SCOPUS, 147 in Science Direct, 89 in PubMed, and 154 in Scielo for 550 articles. Duplicates (N=34) were identified and excluded. Before continuing with article selection, inclusion criteria were established to ensure studies met the following requirements: a) investigating interventions or treatments to improve working memory, b) including relevant keywords in the title or abstract, c) involving a human sample, and d) being written in English. Exclusion criteria included: a) systematic review research, b) restriction to the full article only, c) correlational studies that did not apply working memory intervention, d) cross-sectional studies

that did not involve working memory training, and e) languages other than English (Spanish, Japanese, Portuguese, and Russian).

We extracted information from the articles in the third stage using Microsoft Excel. Titles and abstracts were read, and articles that did not meet the inclusion criteria were excluded. These exclusions included: articles lacking keywords (N=50), languages other than English (N=81), publications before 2019 (N=62), systematic reviews/meta-analyses/literature reviews (N=15), animal studies (N=9), inaccessible/paid articles (N=78), and correlational studies or studies without working memory training/intervention (N=152). After applying these criteria, the fourth stage left us with a selection of 65 articles that met the inclusion criteria and were considered for the systematic review. The fifth phase will present the statistical results. Finally, in the methodological description of this research, it is important to indicate that this project was registered on the Open Science Framework platform with the code DOI 10.17605/OSF.IO/CYPKR.

Results

To obtain results, we reviewed data from 65 articles eligible for analysis.⁴⁷⁻¹¹¹ This data extraction included article information, such as authors, publication year, sample size, training methods, intervention type, evaluation instruments, and results (see Annex 1). Pivot tables were then used to organize this data and present each variable.

To further analyze the data, we tabulated and segmented it. The results were then presented in dynamic graphs that effectively communicated relationships, measures, and percentages. Finally, we calculated measures of central tendency (mean, mode, and standard deviation) to summarize the information, understand the data's dispersion, and refine our analysis and conclusions.

Research sample sizes

In the sample size range, the intervals 30-44 and 45-59 show the highest scores with 16 studies. In contrast, the intervals 135-149 and 195-209 show a score of 1 study. There were 65 studies in total, of which the average is 59.23, with a standard deviation of 38.69. See Figure 2.

Years of publications

We analyzed the distribution of publication years for articles published since 2019. The year 2020 showed a predominance of articles, while there was a decrease in publications in 2023 and 2024 (see Figure 3).

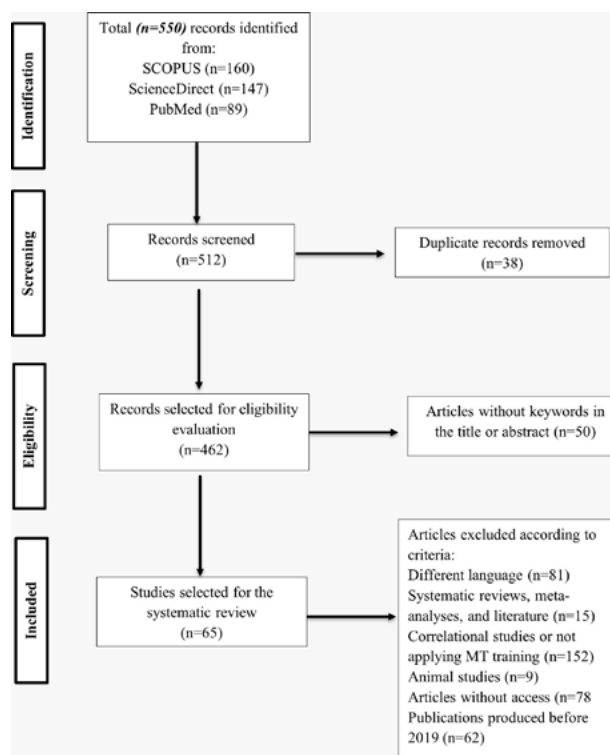


Figure 1. PRISMA flow diagram at four levels.

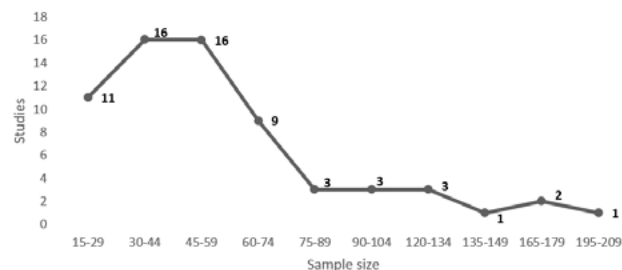


Figure 2. Distribution of sample sizes in reviewed studies.

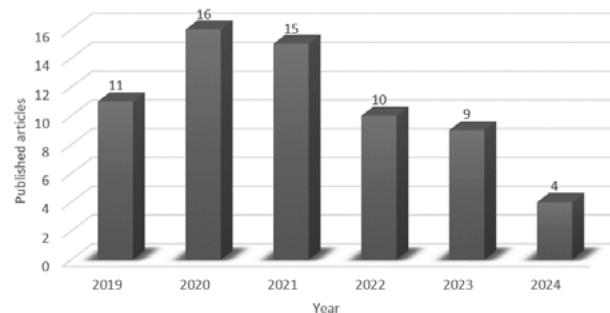


Figure 3. Articles published in recent years.

Research countries

Figure 4 shows the geographical distribution of the studies. China leads with 12 studies (18.5%), followed by Germany (8 studies; 12.3%), the United States (7 studies; 10.8%), and Canada (6 studies; 9.2%).

Types of participants included in the research

The studies employed working memory training on various groups, including healthy individuals (28 studies; 43.1%). Research also involved individuals with substance abuse or other addictions (5 studies; 7.7%) and those with degenerative disorders, severe mental illness, ADHD, brain injury, stroke, or multiple sclerosis (4 studies; 6.2%). In contrast, studies with samples inclu-

ding premature birth, intrusive thoughts, or problematic internet use were the least common (1 study each; 1.5%). See Figure 5 for details.

Age of research participants

The average age of participants across the studies was 28.69 years old (SD = 23.38). Looking at the life stages, 38.5% of the studies involved adults, followed by 15.4% with children and young adults, and 10.8% with only young people. Additionally, a small portion of studies included combined age groups: 1.5% each for children and adolescents, older adults and young adults, and young adults and adults. Figure 6 presents a detailed breakdown of these life stages.

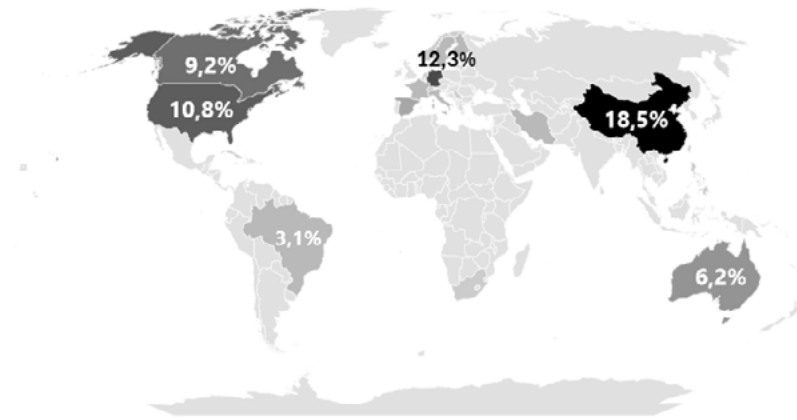


Figure 4.
Geographical distribution of research.

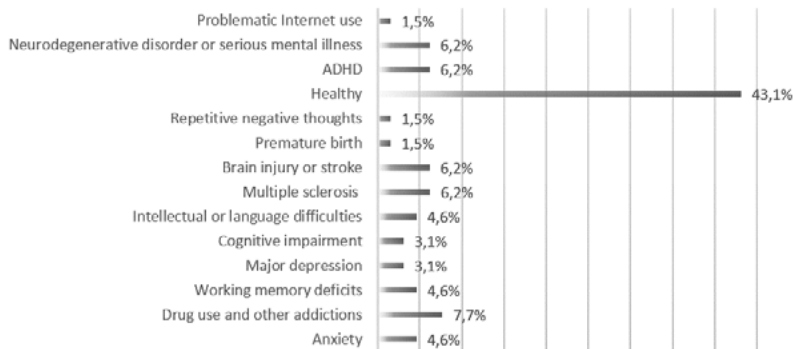


Figure 5.
Type of sample.

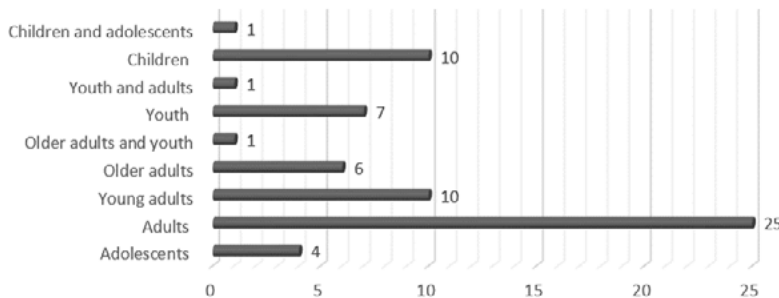


Figure 6.
Participants' evolutionary stage.

Treatments Applied

The studies explored various interventions to improve working memory in healthy individuals and those with diagnosed conditions. Computer-based training was the most common method (41 studies), utilizing programs like Cogmed, Dual n-back tasks, and Lumosity. Electrical stimulation techniques, such as Transcranial Direct Current Stimulation (tDCS), were also employed in 16 studies. Physical training and cognitive stimulation were the least common interventions used in only two studies. Figure 7 provides a visual breakdown of these interventions.

Assessment Instruments Applied

Several tests were administered in the articles, of which the N-back was the most used, specifically in 22 studies, followed by the digit span test and the WAIS-IV in seven studies. These tests were applied in the research to identify the working memory level and evaluate the results obtained from the applied training. Explore Figure 8 to observe the distribution of these tests in the studies.

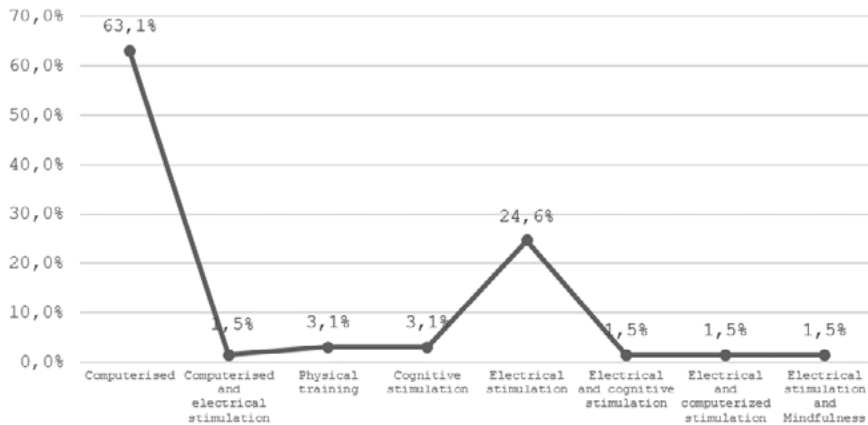


Figure 7. Treatments and training applied.

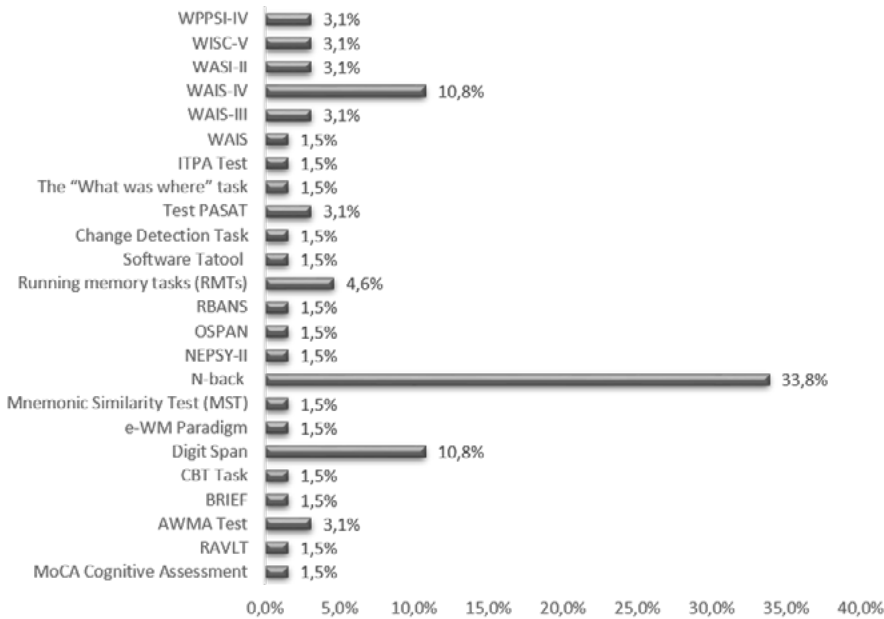


Figure 8. Tests applied in research.

Intervention Time

Four ranges were used to identify the duration of the working memory training intervention in weeks. The range 0-5 weeks shows the highest score, with 58% of the studies showing it, followed by the range 5-10, with 35% of the studies showing it, the range 10-15 weeks, with 5%, and finally, the range 255-260 weeks, with 2% showing it. See Figure 9 to visualize the distribution of treatment and training duration across the studies.

Research Results

The final analysis revealed that 48 published articles showed significant working memory improvement, while the remaining 17 did not. Figure 10 depicts these results.

Discussion

This research conducted a quantitative systematic review of working memory intervention and training methods. We identified 550 articles from databases like SCOPUS, Science Direct, PubMed, and Scielo. After applying inclusion and exclusion criteria, 65 studies were selected for further analysis using descriptive statistics.

Working memory is a critical cognitive function that is especially vulnerable in individuals with neurodevelopmental disorders, learning and language impairments, neurodegenerative diseases, and severe mental illness.²²

This research contributes to the field by examining current working memory treatment processes designed to rehabilitate this executive function and improve clinical practice and intervention strategies.

The research found that most studies originated in Asia and primarily focused on healthy adult populations. Computer-based programs were the most common intervention for working memory improvement, while the N-back test was the preferred method for assessment.

This systematic review highlights the extensive research on working memory interventions. A thorough examination of the existing evidence is essential for psychiatrists, psychologists, neurologists, and other healthcare professionals seeking treatment options for patients with working memory deficits. Furthermore, given its crucial role in daily life activities, working memory training should ideally begin in early childhood (5-8 years old) to promote neurodevelopment in typical children and to target interventions in infants with developmental challenges, such as those born very prematurely.⁸⁹

Working memory interventions and assessments heavily rely on technology and computer programs. This makes the process more accessible and engaging for patients. However, the long-term effectiveness of these interventions remains unclear.⁸⁹ This highlights the need to develop computer-based programs further and poten-

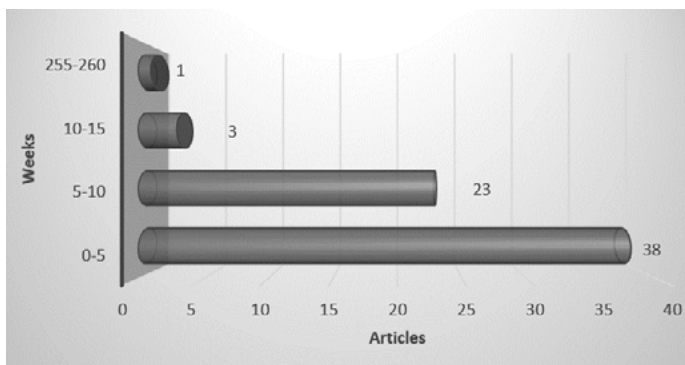


Figure 9.
Intervention Time in Weeks.

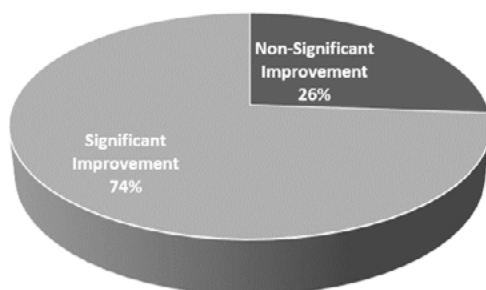


Figure 10.
Research Results.

tially combine them with other interventions. Ideally, these advancements would be based on empirical evidence to ensure sustained effectiveness over time.

This research has two main limitations. First, access to some published articles was limited because they required payment to access the full content (pay-walled). Second, the analysis was restricted to English-language and quantitative studies. Future studies will include articles published in Spanish and other languages to capture a broader range of research on working memory. Additionally, this study focused solely on measurable research. It will be important to consider including qualitative research to gain a more comprehensive understanding of working memory interventions in future work.

This systematic review identified existing working memory training and intervention methods, paving the way for future research directions. One crucial area of inquiry is investigating the long-term sustainability of these treatment methods on working memory capacity. Additionally, exploring the application of new technological intervention tools holds promise, particularly for children and adolescents with cognitive deficits. Finally, future studies should prioritize testing the efficacy of working memory treatments using rating scales tailored to the specific sample population.

References

1. Lezak MD. Neuropsychological assessment. New York: Oxford University Press; 2004.
2. Diamond A. Executive functions. Annual Review of Psychology. 2013;64:135-68. <https://doi.org/10.1146/annurev-psych-113011-143750>
3. Gilbert SJ, Burgess PW. Executive function. Current Biology. 2008;18(2):R110-4. <https://doi.org/10.1016/j.cub.2007.12.014>
4. Baddeley A. The episodic buffer: a new component of working memory? Trends in Cognitive Sciences. 2000;4(11):417-23. [https://doi.org/10.1016/S1364-6613\(00\)01538-2](https://doi.org/10.1016/S1364-6613(00)01538-2)
5. Baddeley A, Hitch G. Working memory. In: Bower GH, editor. Psychology of learning and motivation. New York: Academic Press; 1974. p. 47-89. [https://doi.org/10.1016/S0079-7421\(08\)60452-1](https://doi.org/10.1016/S0079-7421(08)60452-1)
6. Baddeley A. Working memory. Current Biology. 2010;20(4):R136-40. <https://doi.org/10.1016/j.cub.2009.12.014>
7. López M. Memoria de trabajo y aprendizaje: aportes de la neuropsicología. Cuadernos de Neuropsicología / Panamerican Journal of Neuropsychology. 2011;5(1):25-47. <https://www.redalyc.org/articulo.oa?id=439642487003>
8. Prabhakaran V, Narayanan K, Zhao Z, Gabrieli JD. Integration of diverse information in working memory within the frontal lobe. Nature Neuroscience. 2000;3(1):85-90. <https://doi.org/10.1038/71156>
9. Baddeley A. Working memory: looking back and looking forward. Nature Reviews Neuroscience. 2003;4(10):829-39. <https://doi.org/10.1038/nrn1201>
10. Goldman-Rakic PS, Cools AR, Srivastava K. The prefrontal landscape: implications of functional architecture for understanding human mentation and the central executive. Philosophical Transactions of the Royal Society of London. Series B: Biological Sciences. 1996;351(1346):1445-53. <https://doi.org/10.1098/rstb.1996.0129>
11. Konjusha A, Yu S, Mückschel M, Colzato L, Ziemssen T, Beste C. Auricular transcutaneous vagus nerve stimulation specifically enhances working memory gate closing mechanism: a system neurophysiological study. Journal of Neuroscience. 2023;43(25):4709-24. <https://doi.org/10.1523/JNEUROSCI.2004-22.2023>
12. Martín Valle B, Márquez Terraza AV. Relación entre la edad, la memoria de trabajo y la capacidad de reserva cognitiva en adultos mayores de 40 años. Actualidades en Psicología. 2023;37(135):45-54. <https://doi.org/10.15517/ap.v37i135.54325>
13. Elcarte NM, Rivero S. Conocer el cerebro para la excelencia en la educación. Innobasque; 2010.
14. González S, Fernández F, Duarte J. Memoria de trabajo y aprendizaje: implicaciones para la educación. Saber, Ciencia y Libertad. 2016;11(2):147-62. <https://www.redalyc.org/articulo.oa?id=736980267015>
15. López M. Rendimiento académico: su relación con la memoria de trabajo. Revista Electrónica Actualidades Investigativas en Educación. 2013;13(3):1-19. <https://www.redalyc.org/articulo.oa?id=44729878008>
16. López M. Funciones de la memoria de trabajo en los aprendizajes elementales. Paraná: Facultad "Teresa de Ávila"; 2021.
17. Ramos-Galarza C, Acosta-Rodas P, Bolaños-Pasquel M, Lepe-Martínez N. The role of executive functions in academic performance and behaviour of university students. Journal of Applied Research in Higher Education. 2020;12(3):444-55. <https://doi.org/10.1108/JARHE-10-2018-0221>
18. del-Valle MV, Canet-Juric L, Zamora EV, Andrés ML, Urquijo S. Executive functions and their relation to academic performance in university students. Psicología Educativa. 2024;30(1):47-55. <https://doi.org/10.5093/psed2024a2>
19. Vanegas A. La capacidad de la memoria de trabajo en el ámbito educativo: estudio realizado en estudiantes entre 16 y 18 años de edad en la ciudad de Quito. Pontificia Universidad Católica del Ecuador; 2023.
20. Li S, Rosen MC, Chang S, David S, Freedman DJ. Alterations of neural activity in the prefrontal cortex associated with deficits in working memory performance. Frontiers in Behavioral Neuro-

- cience. 2023;17:1213435. <https://doi.org/10.3389/fnbeh.2023.1213435>
21. Rezayat E, Clark K, Mohammad-Reza AD, Noudoost B. Dependence of working memory on coordinated activity across brain areas. *Frontiers in Systems Neuroscience*. 2022;15:787316. <https://doi.org/10.3389/fnsys.2021.787316>
 22. Roording-Ragetlie SL, Pieters S, Wennekers E, Klip H, Buitelaar J, Slaats-Willemse D. Working memory training in children with neurodevelopmental disorders and intellectual disabilities, the role of coaching: a double-blind randomised controlled trial. *Journal of Intellectual Disability Research*. 2023;67(9):842-59. <https://doi.org/10.1111/jir.13047>
 23. Robinson S, Goddard L, Dritschel B, Wisley M, Howlin P. Executive functions in children with autism spectrum disorders. *Brain and Cognition*. 2009;71(3):362-8. <https://doi.org/10.1016/j.bandc.2009.06.007>
 24. Fallon SJ, Smulders K, Esselink RA, van de Warrenburg BP, Bloem BR, Cools R. Differential optimal dopamine levels for set-shifting and working memory in Parkinson's disease. *Neuropsychologia*. 2015;77:42-51. <https://doi.org/10.1016/j.neuropsychologia.2015.07.031>
 25. Deserno L, Sterzer P, Wüstenberg T, Heinz A, Schlagenhaut F. Reduced prefrontal-parietal effective connectivity and working memory deficits in schizophrenia. *Journal of Neuroscience*. 2012;32(1):12-20. <https://doi.org/10.1523/JNEUROSCI.3405-11.2012>
 26. Ioakeimidis V, Haenschel C, Fett AK, Kyriakopoulos M, Dima D. Functional neurodevelopment of working memory in early-onset schizophrenia: a longitudinal fMRI study. *Schizophrenia Research: Cognition*. 2022;30:100268. <https://doi.org/10.1016/j.scog.2022.100268>
 27. Xu X, Xin F, Liu C, et al. Disorder- and cognitive demand-specific neurofunctional alterations during social emotional working memory in generalized anxiety disorder and major depressive disorder. *Journal of Affective Disorders*. 2022;308:98-105. <https://doi.org/10.1016/j.jad.2022.04.023>
 28. Giomi S, Siri F, Ferro A, et al. Executive functions in panic disorder: a mini-review. *Journal of Affective Disorders*. 2021;288:107-13. <https://doi.org/10.1016/j.jad.2021.03.084>
 29. Dell'Osso B, Cinnante C, Di Giorgio A, et al. Altered prefrontal cortex activity during working memory task in bipolar disorder: a functional Magnetic Resonance Imaging study in euthymic bipolar I and II patients. *Journal of Affective Disorders*. 2015;184:116-22. <https://doi.org/10.1016/j.jad.2015.05.026>
 30. Saldarini F, Gottlieb N, Stokes PRA. Neural correlates of working memory function in euthymic people with bipolar disorder compared to healthy controls: a systematic review and meta-analysis. *Journal of Affective Disorders*. 2022;297:610-22. <https://doi.org/10.1016/j.jad.2021.10.084>
 31. Povroznik JM, Ozga JE, Haar C, Engler-Chiurazzi EB. Executive (dys)function after stroke: special considerations for behavioral pharmacology. *Behavioural Pharmacology*. 2018;29(7):638-53. <https://doi.org/10.1097/FBP.0000000000000432>
 32. Chung S, Wang X, Fieremans E, et al. Altered relationship between working memory and brain microstructure after mild traumatic brain injury. *American Journal of Neuroradiology*. 2019;40(9):1438-44. <https://doi.org/10.3174/ajnr.A6146>
 33. Rui C, BeiYao G, RuiDong G, et al. The effects of COVID-19 infection on working memory: a systematic review. *Current Medical Research and Opinion*. 2024;40(2):217-27. <https://doi.org/10.1080/0307995.2023.2286312>
 34. Kroon E, Kuhns L, Colyer-Patel K, Filbey F, Cousijn J. Working memory-related brain activity in cannabis use disorder: the role of cross-cultural differences in cannabis attitudes. *Addiction Biology*. 2023;28(6):e13283. <https://doi.org/10.1111/adb.13283>
 35. Verhallen AM, Renken RJ, Marsman JBC, ter Horst GJ. Working memory alterations after a romantic relationship breakup. *Frontiers in Behavioral Neuroscience*. 2021;15:657264. <https://doi.org/10.3389/fnbeh.2021.657264>
 36. Tyagi R, Arvind H, Goyal M, Anand A, Mohanty M. Working memory alterations plays an essential role in developing global neuropsychological impairment in Duchenne muscular dystrophy. *Frontiers in Psychology*. 2021;11:613242. <https://doi.org/10.3389/fpsyg.2020.613242>
 37. Manglani HR, Fountain-Zaragoza S, Shankar A, Nicholas JA, Prakash RS. Employing connectome-based models to predict working memory in multiple sclerosis. *Brain Connectivity*. 2022;12(6):502-14. <https://doi.org/10.1089/brain.2021.0037>
 38. Herzog N, Hartmann H, Janssen LK, et al. Working memory gating in obesity: insights from a case-control fMRI study. *Appetite*. 2024;195:107179. <https://doi.org/10.1016/j.appet.2023.107179>
 39. Li J, Cao Y, Ou S, Jiang T, Wang L, Ma N. The effect of total sleep deprivation on working memory: evidence from diffusion model. *Sleep*. 2024;47(2):zsae006. <https://doi.org/10.1093/sleep/zsae006>
 40. van der Donk MLA, Hiemstra-Beernink AC, Tjeenk-Kalff AC, van der Leij A, Lindauer RJL. Predictors and moderators of treatment outcome in cognitive training for children with ADHD. *Journal of Attention Disorders*. 2020;24(13):1914-27. <https://doi.org/10.1177/1087054716632876>
 41. Bigorra A. Entrenamiento cognitivo en memoria de trabajo para niños con TDAH: ensayo clínico

- aleatorizado. Universidad Autónoma de Barcelona; 2016. <http://hdl.handle.net/10803/402403>
42. Flor RK, Monir KC, Bitá A, Shahnaz N. Effect of relaxation training on working memory capacity and academic achievement in adolescents. *Procedia - Social and Behavioral Sciences*. 2013;82:608-13. <https://doi.org/10.1016/j.sbspro.2013.06.318>
 43. Yang D, Kang MK, Huang G, Eggebrecht AT, Hong KS. Repetitive transcranial alternating current stimulation to improve working memory: an EEG-fNIRS study. *IEEE Transactions on Neural Systems and Rehabilitation Engineering*. 2024;32:1257-66. <https://doi.org/10.1109/TNSRE.2024.3377138>
 44. Ritakallio L, Fellman D, Salmi J, Jylkkä J, Laine M. Self-reported strategy use in working memory tasks. *Scientific Reports*. 2024;14(1):4893. <https://doi.org/10.1038/s41598-024-54160-3>
 45. Arksey H, O'Malley L. Scoping studies: towards a methodological framework. *International Journal of Social Research Methodology*. 2005;8(1):19-32. <https://doi.org/10.1080/1364557032000119616>
 46. Levac D, Colquhoun H, O'Brien KK. Scoping studies: advancing the methodology. *Implementation Science*. 2010;5:69. <https://doi.org/10.1186/1748-5908-5-69>
 47. Sandberg S, McAuley T. Hospital-based modified Cogmed working memory training for youth with ADHD. *Journal of Attention Disorders*. 2022;26(10):1283-92. <https://doi.org/10.1177/10870547211066487>
 48. Murphy OW, Hoy KE, Wong D, et al. Transcranial random noise stimulation is more effective than transcranial direct current stimulation for enhancing working memory in healthy individuals. *Brain Stimulation*. 2020;13:1370-80. <https://doi.org/10.1016/j.brs.2020.07.001>
 49. Roque-Gutierrez E, Ibbotson P. Working memory training improves children's syntactic ability. *Journal of Experimental Child Psychology*. 2023;227:105593. <https://doi.org/10.1016/j.jecp.2022.105593>
 50. Murphy OW, Hoy KE, Wong D, et al. Effects of transcranial direct current stimulation and transcranial random noise stimulation on working memory in major depressive disorder. *Brain and Cognition*. 2023;173:106105. <https://doi.org/10.1016/j.bandc.2023.106105>
 51. Schmicker M, Menze I, Schneider C, et al. Making the rich richer: frontoparietal tDCS enhances transfer effects of a single-session distractor inhibition training on working memory in high capacity individuals but reduces them in low capacity individuals. *NeuroImage*. 2021;242:118438. <https://doi.org/10.1016/j.neuroimage.2021.118438>
 52. Razza LB, Luethi MS, Zanao T, et al. Transcranial direct current stimulation versus intermittent theta-burst stimulation for working memory improvement. *International Journal of Clinical and Health Psychology*. 2023;23:100334. <https://doi.org/10.1016/j.ijchp.2022.100334>
 53. Aguirre N, Cruz-Gomez AJ, Esbrí SF, et al. Enhanced frontoparietal connectivity after working memory training in multiple sclerosis. *Multiple Sclerosis and Related Disorders*. 2021;52:102976. <https://doi.org/10.1016/j.msard.2021.102976>
 54. Esbrí SF, Tirado AS, Sanchis-Segura C, Forn C. Near transfer effects after adaptive working memory training in multiple sclerosis. *Multiple Sclerosis and Related Disorders*. 2022;67:104182. <https://doi.org/10.1016/j.msard.2022.104182>
 55. Pan D, Hoid D, Gu R, Li X. Emotional working memory training reduces rumination in anxious individuals. *NeuroImage: Clinical*. 2020;28:102488. <https://doi.org/10.1016/j.nicl.2020.102488>
 56. Zhao X, Wang L, Maes JHR. Working memory training in abstinent long-term heroin users. *Addictive Behaviors Reports*. 2020;12:100310. <https://doi.org/10.1016/j.abrep.2020.100310>
 57. Zhao X, Wang L, Maes JHR. Working memory updating training in abstinent methamphetamine users. *Addictive Behaviors Reports*. 2021;14:100385. <https://doi.org/10.1016/j.abrep.2021.100385>
 58. Salmi J, Soveri A, Salmela V, et al. Working memory training normalizes brain activity in adult ADHD. *Human Brain Mapping*. 2020;41(17):4876-91. <https://doi.org/10.1002/hbm.25164>
 59. Papazova I, Strube W, Wienert A, et al. Effects of 1 mA and 2 mA tDCS on working memory performance. *Consciousness and Cognition*. 2020;83:102959. <https://doi.org/10.1016/j.concog.2020.102959>
 60. Živanović M, Paunović D, Konstantinović U, et al. Prefrontal vs parietal tDCS effects on working memory. *Neurobiology of Learning and Memory*. 2021;179:107398. <https://doi.org/10.1016/j.nlm.2021.107398>
 61. Danilewitz M, Gao S, Salehinejad MA, et al. Combined yoga and tDCS intervention improves working memory. *Journal of Integrative Neuroscience*. 2021;20(2):367-74. <https://doi.org/10.31083/j.jin2002036>
 62. Emadi Chashmi SJ, Shahrajabian F, Hasani J, et al. Emotional working memory training in problematic internet use. *Journal of Behavioral Addictions*. 2023;12(3):786-802. <https://doi.org/10.1556/2006.2023.00022>
 63. Tan G, Adams J, Donovan K, et al. Vibrotactile vagus nerve stimulation and working memory. *Brain Stimulation*. 2024;17(2):460-8. <https://doi.org/10.1016/j.brs.2024.04.002>
 64. Wang C, Xu T, Geng F, et al. Training on abacus-based mental calculation enhances visuospatial wor-

- king memory in children. *Journal of Neuroscience*. 2019;39(33):6439-48. <https://doi.org/10.1523/JNEUROSCI.3195-18.2019>
65. Krause-Utz A, Walther JC, Schweizer S, et al. Emotional working memory training in borderline personality disorder. *Psychotherapy and Psychosomatics*. 2020;89:122-4. <https://doi.org/10.1159/000504454>
 66. Khemiri L, Brynte C, Stunkel A, et al. Working memory training in alcohol use disorder. *Alcoholism: Clinical and Experimental Research*. 2019;43(1):135-46. <https://doi.org/10.1111/acer.13910>
 67. Blair M, Goveas D, Safi A, et al. Cogmed training in multiple sclerosis. *Multiple Sclerosis and Related Disorders*. 2021;49:102770. <https://doi.org/10.1016/j.msard.2021.102770>
 68. Wiest GM, Rosales KP, Looney L, et al. Cognitive training in ADHD and SLD. *Brain Sciences*. 2022;12(2):141. <https://doi.org/10.3390/brainsci12020141>
 69. Henry LA, Christopher E, Chiat S, Messer D. Adaptive working-memory intervention for developmental language disorder. *Brain Sciences*. 2022;12(5):642. <https://doi.org/10.3390/brainsci12050642>
 70. Yao J, Song B, Shi J, et al. Cerebellar rTMS effects on working memory. *Brain Sciences*. 2023;13(8):1158. <https://doi.org/10.3390/brainsci13081158>
 71. Deldar Z, Rustamov N, Blanchette I, Piché M. Improving working memory and pain inhibition in older persons using transcranial direct current stimulation. *Neuroscience Research*. 2019;148:19-27. <https://doi.org/10.1016/j.neures.2018.12.007>
 72. Deng Y, Hou L, Chen X, Zhou R. Working memory training improves emotion regulation in drug abstiners. *Neuroscience Letters*. 2021;742:135513. <https://doi.org/10.1016/j.neulet.2020.135513>
 73. Barbazzani B, Speck O, Düzel E. Cognitive training vs EEG-neurofeedback for working memory. *Brain Communications*. 2023;5(2):fcad101. <https://doi.org/10.1093/braincomms/fcad101>
 74. Nissim N, O'Shea A, Indahlastari A, et al. Transcranial direct current stimulation and cognitive training in older adults. *Frontiers in Aging Neuroscience*. 2019;11:340. <https://doi.org/10.3389/fnagi.2019.00340>
 75. Pei G, Yang R, Shi Z, et al. Neurofeedback for working memory in subjective cognitive decline. *Frontiers in Aging Neuroscience*. 2020;12:263. <https://doi.org/10.3389/fnagi.2020.00263>
 76. Ronold EH, Joormann J, Hammar Å. Working memory training in major depressive disorder. *Frontiers in Behavioral Neuroscience*. 2022;16:887596. <https://doi.org/10.3389/fnbeh.2022.887596>
 77. Di Lieto MC, Pecini C, Brovedani P, et al. Working memory training in preterm children. *Frontiers in Neurology*. 2020;11:601148. <https://doi.org/10.3389/fneur.2020.601148>
 78. Ke Y, Wang N, Du J, et al. The effects of transcranial direct current stimulation on working memory training. *Frontiers in Human Neuroscience*. 2019;13:19. <https://doi.org/10.3389/fnhum.2019.00019>
 79. Dziemian S, Appenzeller S, von Bastian CC, et al. Working memory training effects on white matter integrity in young and older adults. *Frontiers in Human Neuroscience*. 2021;15:605213. <https://doi.org/10.3389/fnhum.2021.605213>
 80. Zhao R, He ZY, Cheng C, et al. Combined transcranial direct current stimulation and transcutaneous auricular vagus nerve stimulation for working memory. *Frontiers in Neuroscience*. 2022;16:947236. <https://doi.org/10.3389/fnins.2022.947236>
 81. Nikolin S, Lauf S, Loo CK, Martin D. Effects of high-definition transcranial direct current stimulation of the intraparietal sulcus and dorsolateral prefrontal cortex on working memory and divided attention. *Frontiers in Integrative Neuroscience*. 2019;12:64. <https://doi.org/10.3389/fnint.2018.00064>
 82. Roberts H, Mostazir M, Moberly NJ, et al. Working memory updating training reduces repetitive negative thinking. *Behaviour Research and Therapy*. 2021;142:103871. <https://doi.org/10.1016/j.brat.2021.103871>
 83. Iordan AD, Cooke KA, Moored KD, et al. Neural correlates of working memory training: evidence for plasticity in older adults. *NeuroImage*. 2020;217:116887. <https://doi.org/10.1016/j.neuroimage.2020.116887>
 84. Giehl K, Ophrey A, Reker P, et al. Home-based working memory training in Parkinson's disease. *Journal of Central Nervous System Disease*. 2020;12:1179573519899469. <https://doi.org/10.1177/1179573519899469>
 85. Chan S, Mueller U, Masson MEJ. Far-transfer effects of strategy-based working memory training. *Frontiers in Psychology*. 2019;10:1285. <https://doi.org/10.3389/fpsyg.2019.01285>
 86. Veloso GC, Ty WE. Emotional working memory training reduces anxiety. *Frontiers in Psychology*. 2021;11:549623. <https://doi.org/10.3389/fpsyg.2020.549623>
 87. Zamarreño P, Mateos PM, Valentín A. Working memory training improves episodic memory in older adults. *Frontiers in Psychology*. 2024;15:1314483. <https://doi.org/10.3389/fpsyg.2024.1314483>
 88. Gire C, Beltran Anzola A, Marret S, et al. Visuospatial working memory training in preterm children. *JAMA Network Open*. 2023;6(9):e2331988. <https://doi.org/10.1001/jamanetworkopen.2023.31988>
 89. Hasslinger J, Jonsson U, Bölte S. Neurofeedback and working memory training in ADHD. *Journal of Attention Disorders*. 2022;26(11):1492-506. <https://doi.org/10.1177/10870547211063645>
 90. Kelly CE, Thompson DK, Chen J, et al. Working

- memory training in extremely preterm children. *Human Brain Mapping*. 2020;41:684-96. <https://doi.org/10.1002/hbm.24832>
91. Wu Q, Ripp I, Emch M, Koch K. Cortical responsiveness to working memory training. *Human Brain Mapping*. 2021;42:2907-20. <https://doi.org/10.1002/hbm.25412>
 92. Roording-Ragetlie S, Spaltman M, de Groot E, et al. Working memory training in borderline intellectual functioning. *Journal of Intellectual Disability Research*. 2022;66:178-94. <https://doi.org/10.1111/jir.12895>
 93. Au J, Smith-Peirce RN, Carbone E, et al. Effects of multisession prefrontal transcranial direct current stimulation on long-term memory and working memory in older adults. *Journal of Cognitive Neuroscience*. 2022;34(6):1015-37. https://doi.org/10.1162/jocn_a_01839
 94. Sung CM, Lee TY, Chu H, et al. Multi-domain cognitive training in mild cognitive impairment. *Journal of Global Health*. 2023;13:04069. <https://doi.org/10.7189/jogh.13.04069>
 95. Lawlor-Savage L, Kusi M, Clark CM, Goghari VM. No evidence for an effect of a working memory training program on white matter microstructure. *Intelligence*. 2021;86:101541. <https://doi.org/10.1016/j.intell.2021.101541>
 96. Lochner C, Louw D, Kidd M, Stein DJ. Working memory training in trichotillomania. *Journal of Obsessive-Compulsive and Related Disorders*. 2021;28:100617. <https://doi.org/10.1016/j.jocrd.2020.100617>
 97. Moghadas Tabrizi Y, Yavari Kateb M, Shahrbanian S. Transcranial direct current stimulation enhances visuospatial working memory. *Basic and Clinical Neuroscience*. 2023;14(1):129-36. <https://doi.org/10.32598/bcn.2021.3275.1>
 98. Bonzano L, Pedullà L, Pardini M, et al. Brain activity changes after working memory training in multiple sclerosis. *Brain Imaging and Behavior*. 2020;14:142-54. <https://doi.org/10.1007/s11682-018-9984-z>
 99. Gire C, Beltran Anzola A, Kaminski M, et al. Long-term visuospatial effects of working memory training in preterm children. *BMC Pediatrics*. 2021;21:402. <https://doi.org/10.1186/s12887-021-02867-x>
 100. Zhu X, Huang C, Fan H, et al. The effect of transcranial direct current stimulation combined with working memory training on working memory deficits in schizophrenic patients: study protocol for a randomized controlled trial. *Trials*. 2022;23:826. <https://doi.org/10.1186/s13063-022-06776-5>
 101. Eide LS, Rike PO, Reme SE, et al. Using hypnotic suggestion in the rehabilitation of working memory capacity after acquired brain injury: study protocol for a randomized controlled trial. *Trials*. 2024;25(1):11. <https://doi.org/10.1186/s13063-023-07867-z>
 102. Asseondi S, Hu R, Eskes G, et al. Transcranial direct current stimulation and working memory training in acquired brain injury. *BMC Psychology*. 2020;8(1):25. <https://doi.org/10.1186/s40359-020-00454-w>
 103. Xu C, Wei H. The effect of working memory training on test anxiety symptoms and attentional control in adolescents. *BMC Psychology*. 2024;12(1):101. <https://doi.org/10.1186/s40359-024-01597-w>
 104. Eckardt N, Braun C, Kibele A. Instability resistance training improves working memory in older adults. *Scientific Reports*. 2020;10(1):2506. <https://doi.org/10.1038/s41598-020-59105-0>
 105. Wilke J. Functional high-intensity exercise is more effective in acutely increasing working memory than aerobic walking: an exploratory randomized, controlled trial. *Scientific Reports*. 2020;10(1):12335. <https://doi.org/10.1038/s41598-020-69139-z>
 106. Asseondi S, Hu R, Eskes G, et al. Impact of transcranial direct current stimulation on working memory training is enhanced by strategy instructions in individuals with low working memory capacity. *Scientific Reports*. 2021;11(1):5531. <https://doi.org/10.1038/s41598-021-84298-3>
 107. Salmi J, Vilà-Balló A, Soveri A, et al. Working memory updating training modulates a cascade of event-related potentials depending on task load. *Neurobiology of Learning and Memory*. 2019;166:107085. <https://doi.org/10.1016/j.nlm.2019.107085>
 108. Towe SL, Hartsock JT, Xu Y, Meade CS. Web-based working memory training in HIV and cocaine use disorder. *AIDS and Behavior*. 2021;25(5):1542-51. <https://doi.org/10.1007/s10461-020-02993-0>
 109. Zhu R, Luo Y, Wang Z, You X. Modality effects in verbal working memory updating: transcranial direct current stimulation over human inferior frontal gyrus and posterior parietal cortex. *Brain and Cognition*. 2020;145:105630. <https://doi.org/10.1016/j.bandc.2020.105630>
 110. Bernardi Novaes C, Aparecida Zuanetti P, Hebihara Fukuda MT. Effects of working memory intervention on students with reading comprehension difficulties. *Revista CEFAC*. 2019;21(4):e17918. <https://doi.org/10.1590/1982-0216/201921417918>
 111. Peers PV, Astle DE, Duncan J, et al. Dissociable effects of attention vs working memory training on cognitive performance and everyday functioning following fronto-parietal strokes. *Neuropsychological Rehabilitation*. 2020;30(6):1092-114. <https://doi.org/10.1080/09602011.2018.1554534>

Annex 1. Information extraction table

Nº	Title	Country	Authors (Year)	Type of sample (Nº)	Stage (M age)	Training used	Type of treatment	Test implemented	Intervention time	Results
1	Hospital-Based Modified Cogmed Working Memory Training for Youth With ADHD	Canada	Sandberg et al. (2022) ⁴⁷	Participants with ADHD (40)	Young people (8-16 years old) M = 11.59	Cogmed RM and modified Cogmed	Computerized	WASI-II, WIAT-III, AWMA, TOVA, BRIEF-2, CBCL/TRF, BY-I	3sessions/ week 10 weeks	There was no significant improvement in the experimental group.
2	Transcranial random noise stimulation is more effective than transcranial direct current stimulation for enhancing working memory in healthy individuals: Behavioral and electrophysiological evidence	Australia	Murphy et al. (2020) ⁴⁸	Healthy (49)	Adults (18-65 years old) M = 30.43	Transcranial direct current and transcranial random noise stimulation (tDCS/ tRNS)	Electrical stimulation	WAIS-IV	1 session	The experimental group improved significantly.
3	Working memory training improves children's syntactic ability but not vice versa: A randomized control trial	Cuba	Roque-Gutierrez et al. (2023) ⁴⁹	Healthy (104)	Children (6- 7 years old) M= 7.2	n-back	Computerized	n-back test	16 sessions, 7 weeks	The experimental group improved significantly.
4	Effects of transcranial direct current stimulation and transcranial random noise stimulation on working memory and task-related EEG in major depressive disorder	Australia	Murphy et al. (2023) ⁵⁰	Participants with major depression (49)	Adults (18-65 years old) M= 28.58	Transcranial direct current stimulation (tDCS) and transcranial random noise with DC-offset (tRNS + DC-offset)	Electrical stimulation	WAIS-IV, PASAT arithmetic task, Sternberg task WM	1 session, 5-20-25 minutes	The experimental group improved significantly.
5	Making the rich richer: Frontoparietal tDCS enhances transfer effects of a single-session distractor inhibition training on working memory in high capacity individuals but reduces them in low-capacity individuals.	Germany	Schmicker et al. (2021) ⁵¹	Healthy (86)	Young people (18-30 years old) M= 23.36	Transcranial direct current stimulation (tDCS), a one-session distractor inhibition training (DIIN).	Transcranial and computerized stimulation	Change-detection task	1 session	There was no significant improvement in the experimental group.
6	Transcranial direct current stimulation versus intermittent theta-burst stimulation for the improvement of working memory performance	Brazil	Razza et al. (2023) ⁵²	Healthy (24)	Adults (18-45 years old) M= 28.7	Transcranial direct current stimulation (tDCS) and repetitive theta burst transcranial magnetic stimulation (TBS).	Electrical stimulation	2 n-back tasks	4 sessions/20 minutes, one per week	There was no significant improvement in the experimental group.
7	Enhanced frontoparietal connectivity in multiple sclerosis patients and healthy controls in response to an intensive computerized training focused on working memory	Spain	Aguirre et al. (2021) ⁵³	Participants with multiple sclerosis and healthy (58)	Adults (20-50 years old) M= 35.80	n-back	Computerized	WAIS-III, BRIEF	60 min/day; 4 days	The experimental group improved significantly.
8	Possible evidence of near transfer effects after adaptive working memory training in persons with multiple sclerosis	Spain	Esbrí et al. (2022) ⁵⁴	Participants with multiple sclerosis (35)	Adults (20-45 years old) M= 43.5	1 n-back, 2 n-back, 3 n-back	Computerized	Paced Auditory Serial Addition Test (PASAT), WAIS-III	10 sessions/60 min; 10 days	The experimental group improved significantly.
9	Emotional working memory training reduces rumination and alters the EEG microstate in anxious individuals	China	Pan et al. (2020) ⁵⁵	Anxious Participants (70)	Young people (18-22 years old) M= 21.12	dual n-back, operation span task, running memory task, numerical Stroop task, numerical shifting task	Computerized	n-back test	21 days	The experimental group improved significantly.
10	Training and transfer effects of working memory training in male abstinent long-term heroin users	China	Zhao et al. (2020) ⁵⁶	Heroin using participants (50)	Adults (30-47 years old) M= 45.1	Visuo-spatial n-back	Computerized	Running memory tasks (RMTs)	20 sessions/ 20-21 days	There was no significant improvement in the experimental group.
11	Training and transfer effects of working memory updating training in male abstinent long-term methamphetamine users	China	Zhao et al. (2021) ⁵⁷	Methamphetamine-using participants (32)	Adults (30- 45 years old) M= 39.4	Visual n-back	Computerized	Running memory tasks (RMTs)	20 sessions/ 20-21 days	There was no significant improvement in the experimental group.
12	Working memory training restores aberrant brain activity in adult attention-deficit hyperactivity disorder	Finland	Salmi et al. (2020) ⁵⁸	Participants with ADHD (62)	Adults (18-30 years old) M= 28.6	dual n-back, single n-back	Computerized	BRIEF, running memory-spatial/ verbal, digit span	3 sessions/ 25 min; 5 weeks	The experimental group improved significantly.
13	Effects of 1 mA and 2 mA transcranial direct current stimulation on working memory performance in healthy participants	Germany	Papazova et al. (2020) ⁵⁹	Healthy (46)	Adults (18-35 years old) M= 31.59	Transcranial Direct Current Stimulation (tDCS)	Electrical stimulation	3-back tasks	2 sessions/ 72h apart	The experimental group improved significantly.
14	The effects of offline and online prefrontal vs parietal transcranial direct current stimulation (tDCS) on verbal and spatial working memory	Serbia	Zivanovic et al. (2021) ⁶⁰	Healthy (63)	Adults (20-35 years old) M= 26.76	Transcranial Direct Current Stimulation (tDCS)	Electrical stimulation	Verbal and spatial 3-back tasks	3 sessions	There was no significant improvement in the experimental group.

15	Effect of combined yoga and transcranial direct current stimulation intervention on working memory and mindfulness	Canada	Danilewitz et al. (2021) ⁶¹	Healthy (22)	Young people (18-35 years old) M= 29.05	Transcranial Direct Current Stimulation (tDCS) and mindfulness	Transcranial Stimulation and Yoga	n-back letter task	20min-40min /2 dias	The experimental group improved significantly.
16	The effects of emotional working memory training on internet use, impulsivity, risky decision-making, and cognitive emotion regulation strategies in young adults with problematic use of the internet: A preliminary randomized controlled trial study into possible mechanisms	Iran	Emadi Chashmi et al. (2023) ⁶²	Participants with problematic Internet use (36)	Young adults (18-40 years old) M= 20.27	eWMT (dual n-back task)	Computerized	BART, BIS-11, CERQ-short	20 sessions/ 30-45 min	The experimental group improved significantly.
17	Does Vibrotactile Stimulation of the Auricular Vagus Nerve Enhance Working Memory? A Behavioral and Physiological Investigation	USA	Tan et al. (2024) ⁶³	Healthy (20)	Young adults (18-45 years old) M= 30	The vibrotactile taVNS system	Electrical stimulation	n-back tasks	3 sessions	There was no significant improvement in the experimental group.
18	Training on Abacus-Based Mental Calculation Enhances Visuospatial Working Memory in Children	China	Wang et al. (2019) ⁶⁴	Healthy (144)	Children (6-12 years old) M= 11.93	Abacus-based mental calculation (AMC)	Cognitive stimulation	Visuospatial n-back	2h/5 school years	The experimental group improved significantly.
19	Effectiveness of an Emotional Working Memory Training in Borderline Personality Disorder: A Proof-of-Principle Study	Germany	Krause-Utz et al. (2019) ⁶⁵	Participants with borderline personality disorder (68)	Adults (18-55 years old) M= 45	eWMT (dual n-back task)	Computerized	n-back test	20 min-30 min/28 days	The experimental group improved significantly.
20	Working Memory Training in Alcohol Use Disorder: A Randomized Controlled Trial	Sweden	Khemiri et al. (2019) ⁶⁶	Participants with alcohol use disorder (50)	Adults (18-60 years old) M= 49.6	Cogmed RM	Computerized	Digit Span Task, SWM Task,	5 sessions/ week 5 weeks	The experimental group improved significantly.
21	Does cognitive training improve attention/working memory in persons with MS? A pilot study using the Cogmed Working Memory Training program	Canada	Blair et al. (2021) ⁶⁷	Participants with multiple sclerosis (30)	Adults (18-64 years old) M= 51.07	Cogmed Working Memory Training (CWMT)	Computerized	PASAT, SDMT, WMS-II SS, Stroop (DKEFS Color-Word Interference Test), WAIS-III, Digit span, BRIEF	25 sessions/ 30-45 min	The experimental group improved significantly.
22	Utilizing Cognitive Training to Improve Working Memory, Attention, and Impulsivity in School-Aged Children with ADHD and SLD	USA	Wiest et al. (2022) ⁶⁸	Participants with ADHD (43)	Adolescents (6-17 years old) M= 11.7	Captain's Log program	Computerized	WISC-V, WRAML-2, IVA-2	20 sessions/ 60 min, 4-8 weeks	The experimental group improved significantly.
23	A Short and Engaging Adaptive Working-Memory Intervention for Children with Developmental Language Disorder: Effects on Language and Working Memory	England	Henry et al. (2022) ⁶⁹	Participants with language difficulties (51)	Children (6-10 years old) M= 8	Listening Recall Training Task, The Odd One Out Span task	Computerized	WASH-II, WMTB-C: Digit Recall, Word List Recall, Block Recall	6 weeks	The experimental group improved significantly.
24	Effects of Repetitive Transcranial Magnetic Stimulation at the Cerebellum on Working Memory	China	Yao et al. (2023) ⁷⁰	Healthy (36)	Young adults (18-30 years old) M= 25	Transcranial magnetic stimulation (TMS)	Electrical stimulation	Go-no go, n-back	2 sessions/ one day	The experimental group improved significantly.
25	Improving working memory and pain inhibition in older persons using transcranial direct current stimulation	Canada	Deldar et al. (2019) ⁷¹	Healthy (15)	Adults (55-71 years old) M= 64	Transcranial direct current stimulation (tDCS)	Electrical stimulation	n-back tasks	3h	The experimental group improved significantly.
26	Working memory training improves emotion regulation in drug abstiners: Evidence from frontal alpha asymmetry	China	Deng et al. (2020) ⁷²	Participants abstaining from drugs (40)	Young people (20-40 years old) M= 36.30	Running memory tasks (RMTs)	Computerized	Emotion questionnaire (ERQ)	20 days/ 20-30 min	The experimental group improved significantly.
27	Cognitive training, but not EEG-neurofeedback, improves working memory in healthy volunteers	Germany	Barbazzeni et al. (2023) ⁷³	Healthy (60)	Young people (18-30 years old) M= 24.26	Online feedback, Delayed match-to-sample task (DMST)	Computerized	Mnemonic Similarity Test (MST)	5 days	The experimental group improved significantly.
28	Effects of Transcranial Direct Current Stimulation Paired with Cognitive Training on Functional Connectivity of the Working Memory Network in Older Adults	USA	Nissim et al. (2019) ⁷⁴	Healthy (28)	Older adults (65-89 years old) M= 74	Transcranial Direct Current Stimulation (tDCS), POSI Science BrainHQ	Computerized and transcranial	N-back test	40 min/per day, 2 weeks	The experimental group improved significantly.
29	Enhancing Working Memory Based on Mismatch Negativity Neurofeedback in Subjective Cognitive Decline Patients: A Preliminary Study	China	Pei et al. (2020) ⁷⁵	Participants with subjective cognitive impairment (17)	Older adults (60-80 years old) M= 64.35	Neurofeedback, n- back tasks	Computerized	Auditory Verbal Learning Test (RAVLT)	5 sessions/ 2 weeks	The experimental group improved significantly.
30	Computerized Working Memory Training in Remission from Major Depressive Disorder: Effects on Emotional Working Memory, Processing Speed, Executive Functions, and Associations with Symptoms	USA	Ronold et al. (2022) ⁷⁶	Participants with major depression (20)	Adults (20-60 years old) M= 36.207	Cogmed RM	Computerized	Emotional WM Paradigm (e-WM), Color Word Interference Test (EF)	30-40 min/session, 25 sessions, 5 weeks	The experimental group improved significantly.

31	Adaptive Working Memory Training Can Improve Executive Functioning and Visuo-Spatial Skills in Children with Pre-term Spastic Diplegia	Italy	Di Lieto et al. (2021) ⁷⁷	Participants with premature spastic diplegia (19)	Children (6-13 years old) M= 7.3	Cogmed RM	Computerized	NEPSY-II	25 sessions/ 20 min, 5 weeks	There was no significant improvement in the experimental group.
32	The Effects of Transcranial Direct Current Stimulation (tDCS) on Working Memory Training in Healthy Young Adults	China	Ke et al. (2019) ⁷⁸	Healthy (30)	Young adults (20-25 years old) M= 22	Transcranial Direct Current Stimulation (tDCS)	Electrical stimulation	Verbal and shape n-back tasks	25 min/ 7 sessions	The experimental group improved significantly.
33	Nikolin	Switzerland	Dziemian et al. (2021) ⁷⁹	Healthy (52)	Young people (19-36 years old) Adults (65-77 years old) M= 46.04	Storage and processing: numerical complex span, Relational integration: tower of fame, Supervision: figural task switching	Computerized	Software Tatool	20 sessions, 25-30 min/ session	The experimental group improved significantly.
34	Assessing the Effect of Simultaneous Combining of Transcranial Direct Current Stimulation and Transcutaneous Auricular Vagus Nerve Stimulation on the Improvement of Working Memory Performance in Healthy Individuals	China	Zhao et al. (2022) ⁸⁰	Healthy (132)	Young people (18-26 years old) M= 20.89	Transcranial Direct Current Stimulation (tDCS) and the vibrotactile taVNS system	Electrical stimulation	Spatial 3-back WM task and Digit 3-back WM task	3 sessions/ 90 min	The experimental group improved significantly.
35	iorda	Australia	Nikolin et al. (2019) ⁸¹	Healthy (78)	Young adults (18-40 years old) M= 22.2	High-Definition Transcranial Direct Current Stimulation (HD-tDCS)	Electrical stimulation	The three-back task	20 min	There was no significant improvement in the experimental group.
36	Working memory updating training reduces state repetitive negative thinking: Proof-of-concept for a novel cognitive control training	England	Roberts et al. (2021) ⁸²	Participants with repetitive negative thoughts (124)	Adolescents (10-24 years old) M= 19.37	Tarea de Ecker: negative stimuli, Cognitive (near) transfer: Modified Sternberg task	Computerized	The Backward Digit Span (BDS) of the WAIS-IV	20 sessions/ 28 days	The experimental group improved significantly.
37	Chan	USA	Jordan et al. (2020) ⁸³	Healthy (42)	Older adults (63-75 years old) Young adults (18-28 years old) M= 44.58	The fMRI task, verbal WM task	Computerized	3 T General Electric MR750 scanner	10 days	The experimental group improved significantly.
38	Effects of Home-Based Working Memory Training on Visuo-Spatial Working Memory in Parkinson's Disease: A Randomized Controlled Trial	Germany	Giehl et al. (2020) ⁸⁴	Participants with Parkinson's disease (37)	Adults (45-85 years old) M=64.36	NeuroNation	Computerized	The "What was where"-task	30 min/per session, 5 days, 5 weeks	There was no significant improvement in the experimental group.
39	Far-Transfer Effects of Strategy-Based Working Memory Training	Canada	Chan et al. (2019) ⁸⁵	Healthy (65)	Children (6-9 years old) M= 7.5	Semantic-categorization training tasks, Semantic control tasks, Phonological-rehearsal	Computerized	Forward and backward digit-span tasks, Visual short-term memory (VSTM) task, Problem-solving task	1 session, 1.5h	The experimental group improved significantly.
40	The Effects of Emotional Working Memory Training on Trait Anxiety	Philippines	Veloso et al. (2021) ⁸⁶	Anxious Participants (49)	Young adults (18-40 years old) M= 26.94	Emotional Dual n-Back	Computerized	The Automated Operation Span Task (OSPAN)	20 days	The experimental group improved significantly.
41	Working memory training improves episodic memory in older people: transfer based on controlled retrieval processes	Spain	Zamarreño et al. (2024) ⁸⁷	Healthy (55)	Older adults (60-85 years old) M= 71.85	Counting span, digit span, operation span, and lexical span, matrix span, alignment span, and rotation span	Computerized	Spatial span backward test, digit span backward test and reading span test	10 sessions/ 50 min, 5 weeks	The experimental group improved significantly.
42	Cognitive Training for Visuospatial Processing in Children Aged 5½ to 6 Years Born Very Preterm with Working Memory Dysfunction	France	Gire et al. (2023) ⁸⁸	Participants who were born prematurely (169)	Children (5-6 years old) M= 5.11	Cogmed	Computerized	WPPSI-IV, Communiquer, Lire et Ecrire Pour Apprendre32 battery	25 sessions, 8 weeks	There was no significant improvement in the experimental group.
43	Immediate and Sustained Effects of Neurofeedback and Working Memory Training on Cognitive Functions in Children and Adolescents with ADHD: A Multi-Arm Pragmatic Randomized Controlled Trial	Sweden	Hasslinger et al. (2022) ⁸⁹	Participants with ADHD (202)	Children and Adolescents (9-17 years old) M= 12.6	MinneslekFlex	Computerized	WISC-IV, WAIS-IV	5 sessions/ week 5 weeks	There was no significant improvement in the experimental group.

44	Working memory training and brain structure and function in extremely preterm or extremely low birth weight children	Australia	Kelly et al. (2019) ⁹⁰	Premature or very low birth weight participants (91)	Children (5-9 years old) M= 7.8	Cogmed	Computerized	n- back task	45 min/ 5 days, 5-7 weeks	There was no significant improvement in the experimental group.
45	Cortical and subcortical responsiveness to intensive adaptive working memory training: An MRI surface-based analysis	Germany	Wu et al. (2021) ⁹¹	Healthy (59)	Adults (50-65 years old) M= 55.79	Millisecond Software: n-back task	Computerized	The Digit Span Test	8 weeks	The experimental group improved significantly.
46	Working memory training in children with borderline intellectual functioning and neuropsychiatric disorders: a triple-blind randomised controlled trial	The Netherlands	Roording-Ragellie et al. (2022) ⁹²	Participants with borderline intellectual functioning (72)	Children (10-13 years old) M= 11.7	Cogmed RM	Computerized	Automated Working Memory Assessment (AWMA)	35-45 min/ 5 days, 5 weeks	There was no significant improvement in the experimental group.
47	Effects of Multisession Prefrontal Transcranial Direct Current Stimulation on Long-term Memory and Working Memory in Older Adults	USA	Au et al. (2022) ⁹³	Healthy (55)	Older adults (65-85 years old) M= 71.32	Transcranial Direct Current Stimulation (tDCS)	Electrical stimulation	n-back tasks, LTM training task	5 sessions/ 1h	The experimental group improved significantly.
48	Efficacy of multi-domain cognitive function training on cognitive function, working memory, attention, and coordination in older adults with mild cognitive impairment and mild dementia: A one-year prospective randomized controlled trial	Taiwan	Sung et al. (2023) ⁹⁴	Participants with Mild Cognitive Impairment and Mild Dementia (72)	Older adults (65-85 years old) M= 82.3	Game-based intelligence test by LTPA solution Co., LTD	Computerized	Forward digit span (DS-forward), backward digit span (DS-backward)	24 sessions/30 min, 8 weeks	The experimental group improved significantly.
49	No evidence for an effect of a working memory training program on white matter microstructure	Canada	Lawlor-Savage et al. (2021) ⁹⁵	Healthy (25)	Adults (18-40 years old) M= 30.6	Lumosity: Memory Match, Memory Match Overload, and Memory Lane	Computerized	WAIS-IV: Vocabulary, Similarities, Block Design, Matrix Reasoning, Digit Span, Arithmetic, Symbol Search, and Coding	6 weeks	There was no significant improvement in the experimental group.
50	Working memory training in adults with trichotillomania: A 5-week, single-blind, randomized controlled study	South Africa	Lochner et al. (2021) ⁹⁶	Participants with trichotillomania (36)	Adults (18-55 years old) M= 38.56	Cogmed	Computerized	WAIS-III: Digit Span subtest	25 sessions, 5 weeks	The experimental group improved significantly.
51	Enhancement of Visuospatial Working Memory by Transcranial Direct Current Stimulation on Prefrontal and Parietal Cortices	Iran	Moghadas et al. (2023) ⁹⁷	Healthy (54)	Young adults (18-30 years old) M= 24.3	Transcranial Direct Current Stimulation (tDCS)	Electrical stimulation	Computerized Corsi block tapping task (CBT)	5 days	The experimental group improved significantly.
52	Brain activity pattern changes after adaptive working memory training in multiple sclerosis	Italy	Bonzano et al. (2020) ⁹⁸	Participants with multiple sclerosis (18)	Adults (30-50 years old) M= 45.3	COGNI-TRAcK	Computerized	n-back tasks	30 min/ 5 days, 8 weeks	The experimental group improved significantly.
53	A randomized EPIREMED protocol study on the long-term visuo-spatial effects of very preterm children with a working memory deficit	France	Gire et al. (2021) ⁹⁹	Participants with poor working memory (166)	Children (5-6 years old) M= 5.5	Cogmed JM	Computerized	WPPSI-IV	2 sessions, 5-8 weeks	The experimental group improved significantly.
54	The effect of transcranial direct current stimulation combined with working memory training on working memory deficits in schizophrenic patients: study protocol for a randomized controlled trial	China	Zhu et al. (2022) ¹⁰⁰	Participants with schizophrenia (120)	Adults (18-60 years old) M= 40	Transcranial direct current stimulation (tDCS) and memorize a series of continuous items.	Electrical and cognitive stimulation	Repeatable Battery for the Assessment of Neuropsychological Status (RBANS), MATRICS Consensus Cognitive Battery (MCCB), Wechsler Adult Intelligence Test Brief Version (WAIS-R)	20 min/day (tDCS), 40 min/day (WMT); 2 weeks	The experimental group improved significantly.
55	Using hypnotic suggestion in the rehabilitation of working memory capacity after acquired brain injury: study protocol for a randomized controlled trial	Norway	Eide et al. (2024) ¹⁰¹	Participants who suffered a brain injury (90)	Adults (18-67 years old) M= 50	Hypnotic inductions	Cognitive stimulation	WM index from WAIS-IV, Behavior Rating Inventory of Executive Function-Adult version (BRIEF-A)	1h/day, 4 days/week, 5 weeks	The experimental group improved significantly.
56	BRAINSTORMING: A study protocol for a randomized double-blind clinical trial to assess the impact of concurrent brain stimulation (tDCS) and working memory training on cognitive performance in Acquired Brain Injury (ABI)	England	Assecondi et al. (2020) ¹⁰²	Participants with acquired brain damage (40)	Adults (18-69 years old) M= 50	Transcranial direct current stimulation (tDCS) and n-back tasks	Electrical stimulation	WAIS-IV, WMS-IV	20 min/day, 2 weeks	The experimental group improved significantly.

57	The effect of working memory training on test anxiety symptoms and attentional control in adolescents	China	Xu et al. (2024) ¹⁰³	Anxious Participants (40)	Adolescents (11-17 years old) M= 14.05	Dual n-back task	Computerized	The Go/No go task, n-back task	10 days	There was no significant improvement in the experimental group.
58	Instability Resistance Training improves Working Memory, Processing Speed and Response Inhibition in Healthy Older Adults: A Double-Blinded Randomized Controlled Trial	Germany	Eckardt et al. (2020) ¹⁰⁴	Healthy (68)	Older adults (65-79 years old) M= 71.3	Instability resistance training or resistance training on unstable surfaces (concurrent balance and resistance training)	Physical training	Digit Memory Test, Digit Symbol Substitution Test	10 weeks	The experimental group improved significantly.
59	Functional high intensity exercise is more effective in acutely increasing working memory than aerobic walking: an exploratory randomized, controlled trial	Germany	Jan Wilke (2020) ¹⁰⁵	Healthy (35)	Young adults (18-30 years old) M= 26.7	High-intensity functional training (HIIFT)	Physical training	The Digit Span test, Trail Making test (TMT), The Stroop test	15 min/30 exercise cycles	The experimental group improved significantly.
60	Impact of tDCS on working memory training is enhanced by strategy instructions in individuals with low working memory capacity	England	Assecondi et al. (2021) ¹⁰⁶	Participants with poor working memory (84)	Young adults (18-39 years old) M= 20.6	Transcranial Direct Current Stimulation (tDCS)	Electrical stimulation	n-back tasks: Adaptive spatial n-back task, fixedload- visual n-back task	2 days	The experimental group improved significantly.
61	Working memory updating training modulates a cascade of event-related potentials depending on task load	Finland	Salmi et al. (2019) ¹⁰⁷	Healthy (48)	Young adults (18-30 years old) M=22	Dual n-back task	Computerized	WAIS, BDI-II	3 sessions/ week, 20-25min/ session 5 weeks	There was no significant improvement in the experimental group.
62	WebBased Cognitive Training to Improve Working Memory in Persons with CoOccurring HIV Infection and Cocaine Use Disorder: Outcomes from a Randomized Controlled Trial	USA	Towe et al. (2020) ¹⁰⁸	Participants with HIV and cocaine use disorder (58)	Adults (18-64 years old) M= 48.97	Lumosity	Computerized	Wechsler Test of Adult Reading (WTAR), WAIS-IV: Digit Span, HVLTR, BVMTR	48 sessions, 10 weeks	The experimental group improved significantly.
63	Modality effects in verbal working memory updating: Transcranial direct current stimulation over human inferior frontal gyrus and posterior parietal cortex	China	Zhu et al. (2020) ¹⁰⁹	Healthy (51)	Adolescents (17-22 years old) M= 18.9	Transcranial Direct Current Stimulation (tDCS)	Electrical stimulation	Auditory and visual letter 3-back tasks	20min-50 min/ session	The experimental group improved significantly.
64	Effects of working memory intervention on students with reading comprehension difficulties	Brazil	Bernardi Novaes et al. (2019) ¹¹⁰	Participants with reading comprehension difficulties (43)	Children (8-10 years old) M= 9	Games and ludic activities-based strategies for the development of five abilities: Categorization; Sequencing of simple and complex orders; Creation of visual images; Memorization of words and numerals; and Memorization of non-words	Computerized	Subtest 5 of Auditory Sequential Memory of the Illinois Test of Psycholinguistic Abilities - ITPA, Meaningless Words Repetition Test - RPSS, Auditory and Reading Comprehension Contrastive Test- reading comprehension sub-item (TCCAL - Let)	15 sessions/ 1h each, 8 weeks	The experimental group improved significantly.
65	Dissociable effects of attention vs working memory training on cognitive performance and everyday functioning following front-parietal strokes	England	Peers et al. (2020) ¹¹¹	Participants who suffered a cerebrovascular accident (23)	Adults (28-74 years old) M= 59	Cogmed	Computerized	AWMA Dot Matrix Test, AWMA Spatial Span Test	20 sessions, 4-5 weeks	The experimental group improved significantly.